# APPENDIX L Soil Characterisation Report

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9 September 2022

2664.22b (Rev 1)

Attn: Louise Whitley

**Addendum: Revised Soil Characterisation – Havieron Proposed Haul Road Route**

A Soil Characterisation Report for the Havieron Project was completed by Landloch in September 2020. Following completion of the Soil Characterisation Report, a new haul road route has been proposed by Newcrest. The proposed haul road route falls outside of the area previously surveyed by Landloch.

A memorandum that characterises the soils of the proposed haul road route can be found as an addendum to this report.

If you have any questions regarding this report, please contact me.

Regards

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# HAVIERON SOIL CHARACTERISATION REPORT

Newcrest Mining Limited

September 2020

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**Client:** Newcrest Mining Limited

## Review History

| Version Number | Prepared by: | Reviewed by: | Date |
|---|---|---|---|
| Rev 0 (draft) | I. Kelder | E. Howard | 03/08/2020 |
| Rev 1 (Final) | I. Kelder | E. Howard | 27/08/2020 |
| Rev 2 (Revised) | I. Kelder | E. Howard | 03/09/2020 |

# EXECUTIVE SUMMARY

Newcrest Mining Limited (Newcrest) are preparing environmental assessments as part of a due-diligence exploration program for the Havieron Project. Landloch have undertaken a targeted soil and landform survey for the Boxcut Impact Area (0.44ha), the broader project area (3,816ha) and the service corridor (1,532ha). The objective of the program was to define, map, and characterise the major soil types/associations and landforms within the project area.

A total of 21 soil pits were inspected at the following locations:

- 1 soil inspection site within the Boxcut Impact Area;
- 12 soil inspection sites within the broader Project area; and
- 8 soil inspection sites within the service corridor.

Site information and soil morphology were recorded at each location according to the Australian Soil and Landscape Survey Field Handbook (NCST 2008) and the soils classified using the Australian Soil Classification (Isbell 2002). Samples were collected from all locations, with the number of samples varying with the depth of the soil pit achieved. A total of 77 soil samples from 21 sites were collected. Observations and laboratory results were used to develop soil mapping units (SMUs). Three SMUs were developed to capture the variation in soils in the project area:

- Deep Sands are wind-blown aeolian sands associated with sand dunes present throughout the landscape. These soils are dominated by fine sands with no appreciable silt or clay and no pedological development.
- Gradational Loams are characterised by a thin layer of wind-blown aeolian sands that grade rapidly within the profile to sandy loam, with a gradual increase in clay content from clay loam to light clay at depth. The influence of wind-blown sands are less apparent in these soils. Included in this unit are a:
  - Non-saline and non-sodic sub-unit (not saline or sodic)
  - Saline and sodic sub-unit (highly saline and sodic)
- Gradational Sands are similar to the Deep Sands, except for a change in texture from sand to loam in the deeper B horizon. These soils are characterised by a buried horizon at depth that represents the original soil profile that was covered in wind-blown aeolian sands.

Wind erosion

No quantitative wind erosion modelling was undertaken. However, based on the soil characterisation data for Havieron, and experience on other sites with aeolian sands, it is likely that wind erosion will be of concern for the Deep Sands and Gradational Sands. In particular, the surface sands that have low clay contents.

If the Deep Sands and Gradational Sands are disturbed and placed in a landform orientated perpendicular (running north-south) to the current prevailing wind, the risk of wind erosion (to effectively cause dune migration) increases, and successful revegetation of the highly erodible crest of the landform will be particularly difficult. Orienting the landform in an east-west direction would be desirable if practicable.

If this orientation is not possible, armouring of the windward side (and particularly the crest) will be required. This will be necessary until vegetation is established and able to provide surface erosion resistance.

Additionally, incorporation of clays into the surface layers can improve aggregation, increase the effective particle size and increase erosion resistance. Incorporation of 2-4t/ha of clay (to a depth of 25mm) has been shown to greatly reduce wind erosion on sandy loam soils. The clays present in the subsoil of the Gradational Loams may be potentially useful for this purpose.

Water erosion

The Deep Sands and Gradational Sands are likely to be prone to water erosion when placed on landforms, even with relatively low batter heights and shallow angles. Previous testing of similar materials indicates that dune sands will generally erode at rates such that they are prone to rilling even when placed on relatively low embankments (<10m). As such, there are likely to be serious practical impediments to successful rehabilitation of long slopes with the sands. Given this, the Deep Sands and Gradational Sands should only be used on shallow, short slopes. Placement of these soils on landform shapes that encourage the concentration of flows will likely be at a higher risk of the development of rill and gully erosion. Additionally, placement of these soils on benches or overlying dispersive wastes may also result in significant erosion.

The Non-saline and Non-sodic Gradational Loams have a higher clay content which reduces their permeability when compared to the Deep Sands and Gradational Sands. These soils are less prone to detachment when exposed to runoff but will be more susceptible to erosion under intense storm events due to their lower permeability. The soils would benefit from the addition of a rock armour or tree debris to reduce the impact of overland flows on the sandy materials if used on batter slopes. The Saline and Sodic Gradational Loams should not be used due to the risk of dispersion.

Growth media and stripping depth

The Deep Sands have few limitations from a growth media perspective. They are generally non-saline, non-sodic, slightly acidic to circum-neutral. However, the dominance of the sand fraction and lack of appreciable clay indicates a limited capacity to store water for plant growth, and a low capacity to hold and retain nutrients. As such, use of the Deep Sands for rehabilitation may be limited by their physical properties. Establishment of vegetation or application of rock armour may assist in limiting the impact of wind and water erosion.

There are no limitations to the stripping depth of the Deep Sands. These soils can be stripped to any depth (or until a significant change in material type is observed), provided that they are managed appropriately when stockpiled and when used as a growth medium for rehabilitation. For the purposes of this report, it is assumed that the topsoils will be stripped to 100mm.

The Gradational Sands are very similar to the Deep Sands in terms of their characteristics when stripped. The key characteristic of the Gradational Sands is the change in texture

at 1m. Given that stripping is unlikely to occur to this depth, the Gradational Sands should be managed as per the Deep Sands; that is, topsoils stripped to 100mm.

The Non-saline and Non-sodic Gradational Loams have few limitations from a growth media perspective. This soil type is non-saline, non-sodic, and are suitable for stripping. The Saline and Sodic Gradational Loams are highly saline and sodic soils occurring in lower sections of the landscape and in proximity to dry lakes. These soils should not be stripped, as the high salinity and sodicity is likely to be a limiting factor for their use in rehabilitation.

The Gradational Loams have a higher abundance of clay in the subsoil, increasing their capacity to store and retain water for plant use. Stripping of the (non-sodic and non-saline) sandy topsoils should occur to 100mm, and stripping of the clayey subsoils to 400mm, with a total stripping depth of 500mm assumed. Subsoil stripping will only occur in the area of the boxcut area.

Volumes of potential soil to be stockpiled are provided for the boxcut and the proposed infrastructure areas and WRD. The estimated volume of soil resources available is provided below:

- Topsoil: 148,062m$^3$
- Subsoil: 1,774m$^3$

Stockpiling

Both the Deep Sands and Gradational Sands are susceptible to wind erosion and will require management to reduce this risk. Limiting the height of the stockpiles to 2.0m should reduce the risk of wind erosion. Additionally, application of surface treatments (e.g. surface tackifier or cover) should be considered to further reduce the wind erosion risk. As the Gradational Loams are less prone to wind erosion, stockpile depths up to 4.0m could be considered for this soil type.

Respreading

Once the soil has been respread and directly prior to seeding, the final topsoil surface will require light ripping to break any surface crusting. Landloch has observed surface sealing greatly impacts on germination rates, and a site-specific seeding strategy should be developed based on field trial results using the specific rehabilitation material.

The precise rereading strategy will be determined by the requirements of the landforms. It is likely that the topsoil will require incorporation of rockier materials (wastes) to ensure erosional stability. In this situation this may require mixing using a dozer, either by pushing down rock and soil from the crest of the batter, or by spreading a layer of soil over a layer of waste rock and contour ripping to mix.

Soil amendments

The nutrient status of the soils across the project area is low, however, native vegetation is adapted to grow in this environment. For rehabilitation it is recommended to replace or supplement nutrients lost through disturbance to encourage rapid establishment of vegetation.

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# 1 INTRODUCTION

Newcrest Mining Limited (Newcrest) are preparing environmental assessments as part of a due-diligence exploration program for the Havieron Project. The Havieron Project is a farm-in joint venture agreement between Newcrest and Greatland Gold Ltd, located 45km east of the Telfer Gold Mine. As part of the due-diligence exploration program, Landloch have been commissioned to undertake a soil and waste characterisation study. This report presents the results of the soil characterisation. The findings of the waste characterisation will be presented separately. The following is included in this report:

- A description of the type and characteristics of the topsoils and subsoils;
- Classification of the soils in line with the Australian Soil Classification and Soil Groups of Western Australia;
- The resultant soil maps of the area and allocation of soil mapping units; and
- Soil stripping depth, volumes, and soil amelioration recommendations.

## 1.1 Background

The area surveyed is located within Greatland Gold's exploration tenement E45/4701 (Figure 1). A 7.5km by 5.5km (3,816ha) Project Area has been defined (Figure 2). Within this area, assessment of the Boxcut impact area is required for approvals. The Boxcut impact area is 0.44ha in size. In addition to the Boxcut impact area, a service corridor is intended to be constructed between the Project area and the existing Telfer mine site. The service corridor is approximately 68km long and 1,532ha in size (Figure 3). Accordingly, there are three areas to be investigated:

- The Boxcut impact area (0.44ha);
- Wider project area (3,816ha); and
- Service corridor (68km).

# 2 OUTLINE OF APPROACH

## 2.1 Regulatory requirements

The Department of Mines, Industry Regulation and Safety (DMIRS) Statutory Guidelines for Mine Closure Plans (DMIRS 2020a) state that, "*Comprehensive characterisation of materials (including soils and wastes) is critical to effective closure planning and successful progressive rehabilitation. This process should start during the exploration phase and continue throughout the life of the mine. Characterisation of material allows for separation and selective placement of materials considered beneficial to rehabilitation and materials that may inhibit rehabilitation.*"

Characterisation of the existing soil resource is vital, "*to maintain the variety and integrity of physical landforms so that environmental values are protected*" (EPA 2018). Soils provide both a growth medium for vegetation and influence the hydrological function of the land surface. Understanding the soil resource will assist in development of management techniques for stripping, handling, and storage of topsoil and subsoil. At closure, strategic placement of the soil resource can greatly increase the likelihood of successful rehabilitation and assist in meeting closure completion criteria.

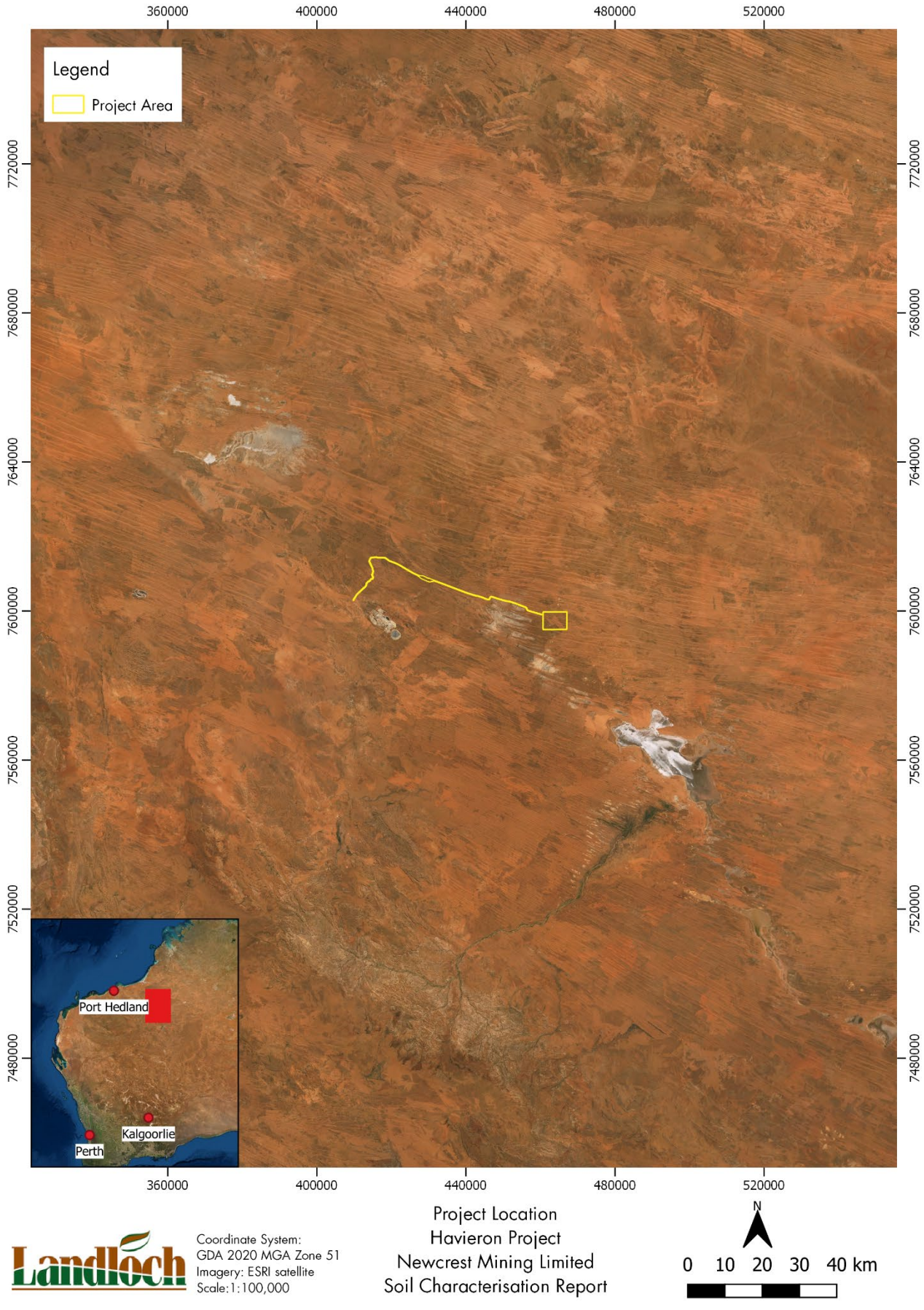



**Figure 1:** Havieron project area

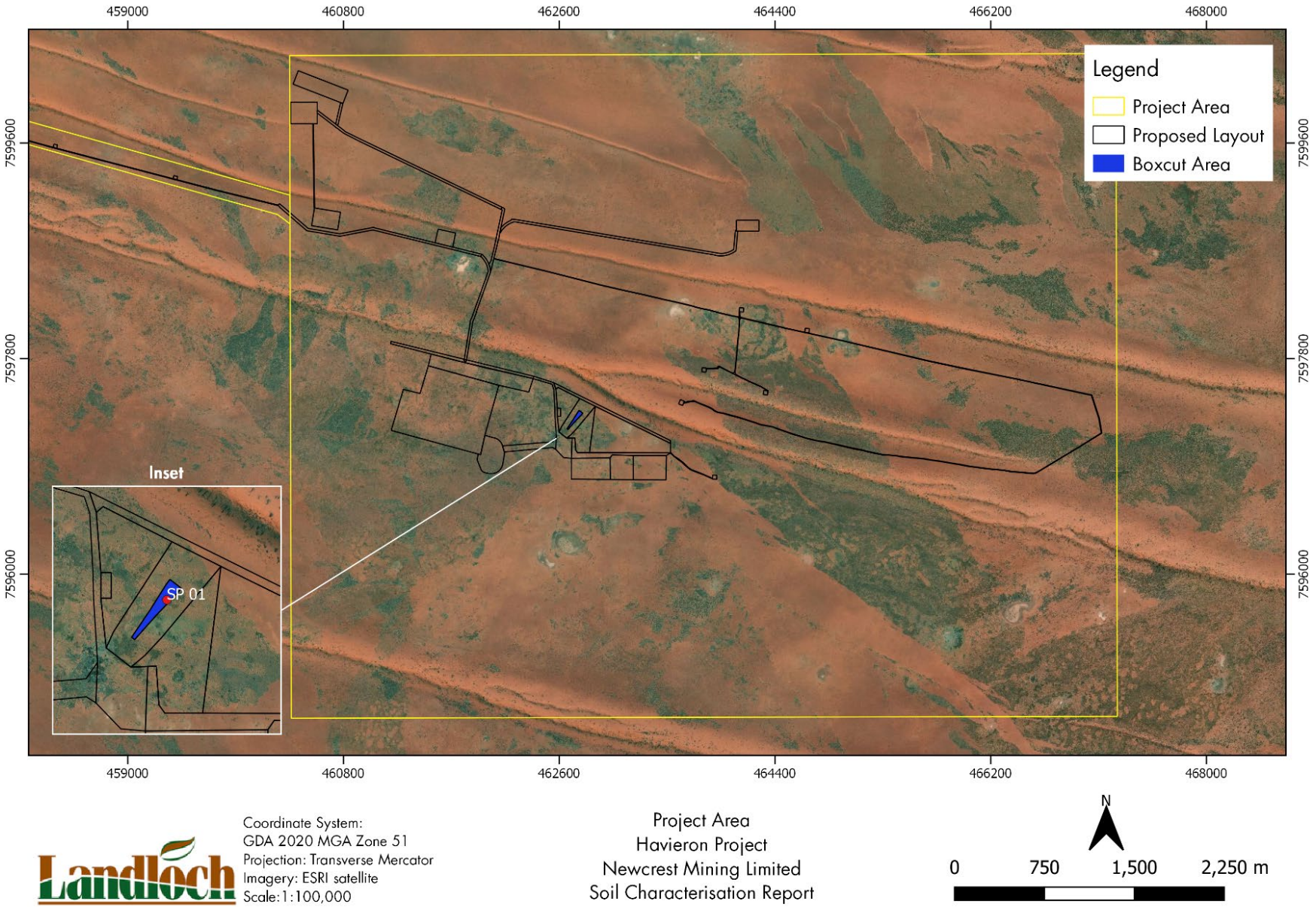



**Figure 2:** Havieron Project area illustrating boxcut

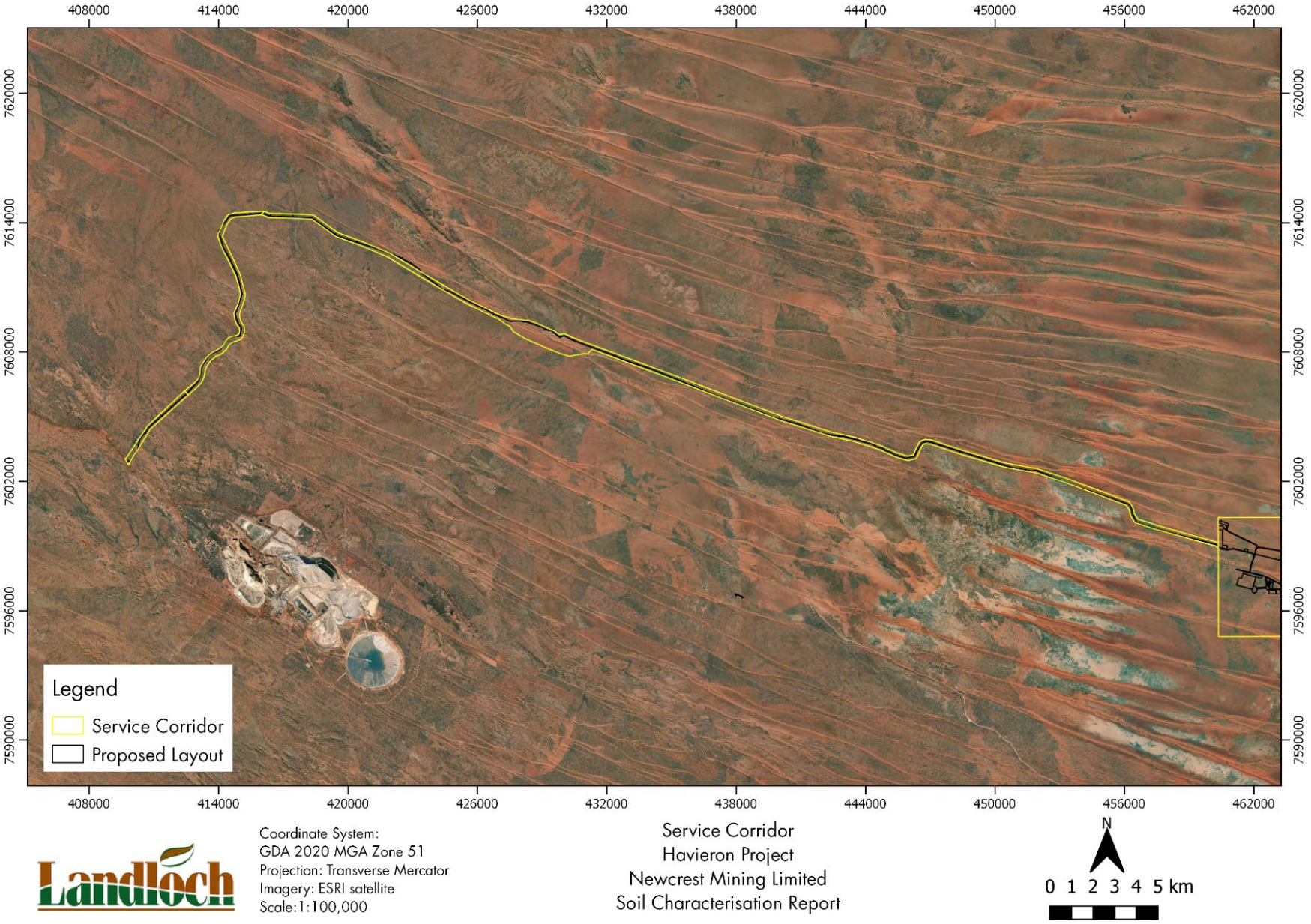



**Figure 3:** Havieron Project area illustrating service corridor

As outlined by the Department of Mines and Petroleum (now DMIRS) in the Draft Guidance for Material Characterisation (DMP 2016), baseline soil characterisation is undertaken for the purpose of:

- Estimating the quantity and quality of the soil resource (topsoil and subsoil) including each major soil type;
- Characterising the baseline growth media attributes of each major soil type including nutrient status; and
- Evaluating potential risks associated with salinity, wind erosion, and water erosion.

In addition to this, DMIRS (2020b) Mining Proposal Guidance states that regarding soils, the following is recommended:

- A description of the major soils occurring in the project area including the indicative volume and characterisation of topsoil and subsoil available for rehabilitation.
- Where there are multiple soil types identified, a map showing the spatial extent of each identified soil type in the project area shall be provided. The map should include a scale bar, latitude and longitude co-ordinates, date of field survey, and regional map location. Soils may be classified according to the WA Soil groups outlined in Schoknecht and Pathan (2013).
- Adequate characterisation of soils to ensure that the risk posed by adverse components can be determined.
- Reference to the characterisation methodologies used.
- Interpretation of baseline data and broad implications for risk assessment and treatments.
- Relevant technical reports attached as appendices (within the Mining Proposal).

Lastly, there is a requirement to meet Newcrest's standard for Land Use and Disturbance Management (Newcrest 2016). Relevant requirements within this document are:

- Planning:
    - Map land use domains across the operation that define the permitted land use and constraints in each area.
- Develop and implement operational procedures for land management including inspections and monitoring programs for the following areas:
    - Land clearance and vegetation removal authorisation;
    - Sediment and erosion control; and
    - Topsoil management.

To meet these requirements, a targeted soil and landform survey and sampling program was conducted. The objective of the program was to define, map, and characterise the major soil types/associations and landforms within the project area. In addition to the observations made during the field survey, laboratory analysis of selected soil samples provides further insight into the limitations and opportunities that the soils present for rehabilitation and closure.

## 2.2 Survey approach

Soils were to be surveyed in two distinct areas that required different surveying approaches:

- Havieron project area containing the Boxcut Impact Area (0.45ha) and the surrounding broader project area (3,816ha); and
- Service corridor connecting Havieron and Telfer (1,532ha).

These distinct areas are shown in Figures 4 and 5 by the yellow polygons. The Havieron project area is rectangular in shape and the survey approach outlined in the Guidelines for Surveying Soil and Land Resources (McKenzie *et al.* 2008) is appropriate. Based on this guideline, the required scale of soil mapping and the size of the proposed survey area dictates the necessary number of soil inspection sites. For the objective of assessing a project's feasibility or for extensive land use planning, an inspection site every 100-400ha is required for the 'low semi-detailed' (1:100,000) intensity level of assessment. This scale of mapping delineates areas of approximately 40ha in size and will detail groups of soils with similar properties. For the objective of 'medium semi-detailed' project planning, an inspection site every 20-100ha is consistent with a mapping scale of 1:50,000 and delineates areas of approximately 10ha in size. The survey of the Havieron project area was conducted at these two scales:

- 'Medium semi-detailed' in the Boxcut Impact Area, targeting an inspection site density of 50ha; and
- 'Low semi-detailed' in the broader project area, targeting an inspection site density of 400ha.

The service corridor is linear and requires a different surveying approach. Survey of the service corridor was performed in accordance with Soil Science Australia's recommendations for surveying linear infrastructure (SSA 2013). Surveying of the service corridor was performed using inspection sites spaced at 6-7km. This was slightly less than recommended but was adopted given the uniformity in soil types along the corridor (it essentially runs within an interdune area and only intersects calcrete zones in discrete locations).

Based on the above, 21 soil inspection sites were selected including:

- 8 soil inspection sites within the service corridor;
- 1 soil inspection sites within the Boxcut Impact Area; and
- 12 soil inspection sites within the broader Project area.

The co-ordinates of the 21 soil inspection sites are provided in Table 1.

**Table 1:** Sample co-ordinates (GDA 94 Zone 51)

| Sampling Point ID | Eastings (mE) | Northings (mS) |
|---|---|---|
| TP 01 | 429907 | 7608704 |
| TP 02 | 462757 | 7597311 |
| TP 03 | 463068 | 7597271 |
| TP 04 | 463405 | 7597081 |
| TP 05 | 463860 | 7596810 |
| TP 06 | 462640 | 7598930 |
| TP 07 | 465100 | 7597040 |
| TP 08 | 465083 | 7597916 |
| TP 09 | 461695 | 7598736 |
| TP 10 | 464700 | 7597502 |
| TP 11 | 463314 | 7598318 |
| TP 12 | 464290 | 7599013 |
| TP 13 | 464145 | 7597345 |
| TP 14 | 464139 | 7598019 |
| TP 15 | 430270 | 7608650 |
| TP 16 | 451250 | 7602620 |
| TP 17 | 441770 | 7604400 |
| TP 18 | 419376 | 7613503 |
| TP 19 | 435580 | 7606640 |
| TP 20 | 424190 | 7611140 |
| TP 21 | 414960 | 7611231 |

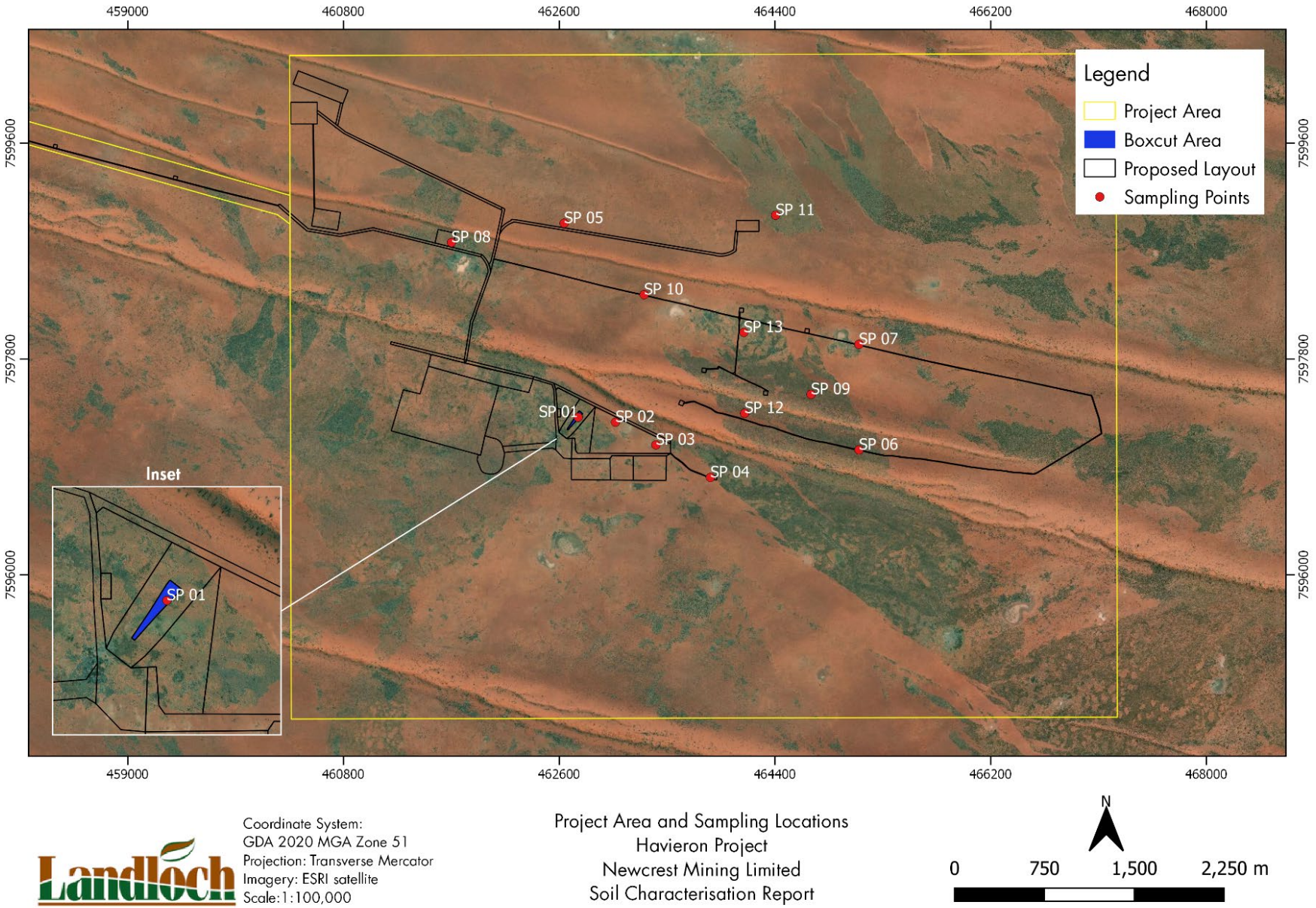



**Figure 4:** Soil inspection site locations – Havieron project area including the box cut

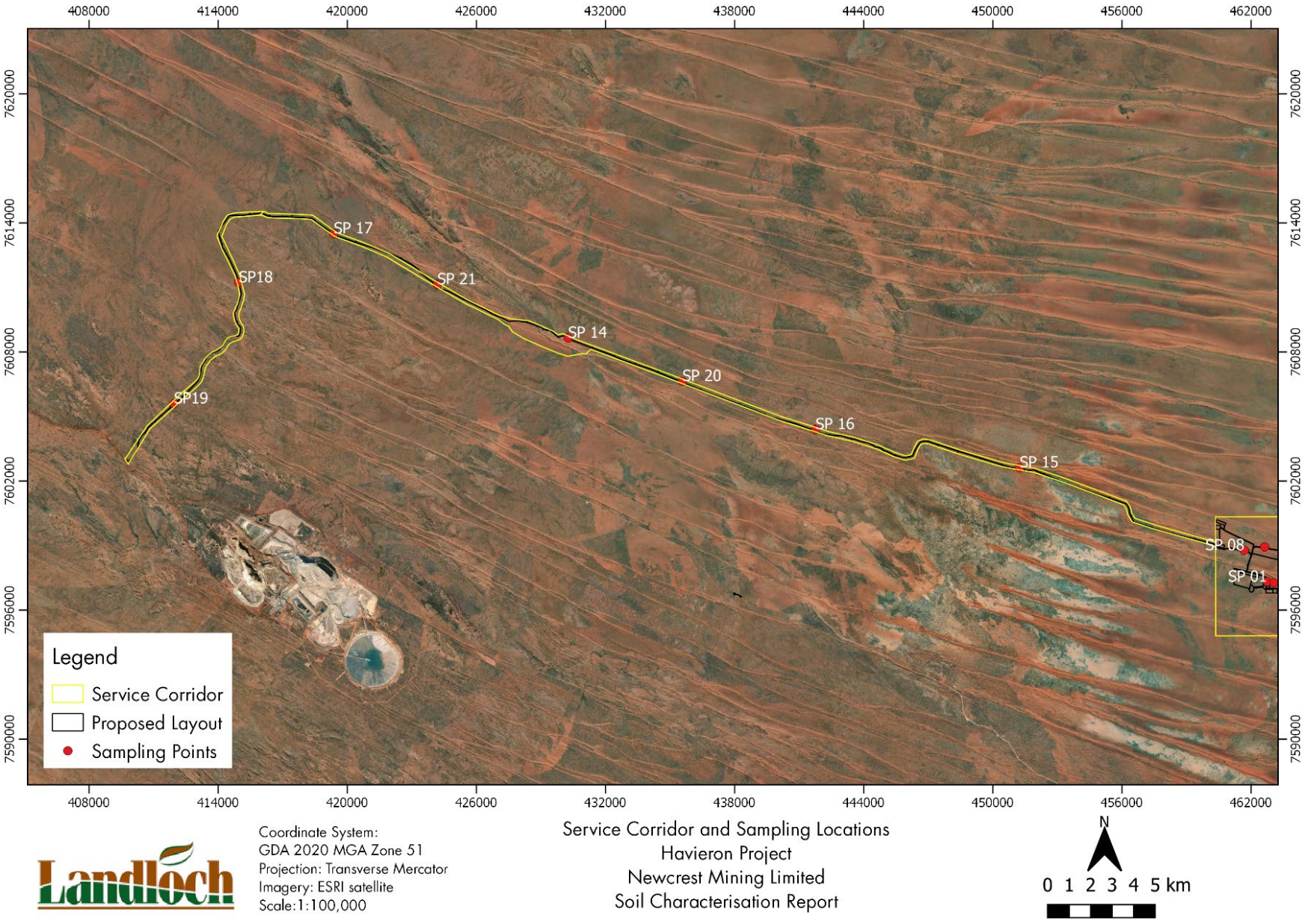



**Figure 5:** Soil inspection site locations - Service corridor

## 2.3 Sampling methodology

Soil inspection sites locations are marked in Figures 4 and 5. Sites were located within heritage-approved areas or previously cleared tracks where possible. Sampling points 18 and 19 occurred in a section not currently covered by a permit, with surface samples taken only by hand.

Nineteen soil test pits and 2 hand samples across the project area were pre-determined for investigation and located by Global Positioning System (GPS) in the field. Test pits were constructed at each location. Test pits were generally 2.0m wide and 1.5m deep.

Site information and soil morphology were recorded at each location according to the Australian Soil and Landscape Survey Field Handbook (NCST 2008) and the soils classified using the Australian Soil Classification (Isbell 2002). Samples were collected from all locations, with the number of samples varying with the depth of the soil pit achieved. A total of 77 soil samples from 21 sites were collected. One sample of the topsoil (A) horizon and two to three samples from the diagnostic (B) horizon were collected at each location.

All soil samples collected were transported to Landloch's soils facility in Bibra Lake, Perth and assessed for pH, EC, Emerson dispersion, Munsell colour, fine/coarse fraction percentage, and hand texture (Table 1). In addition to this, 20 of the 77 soil samples were submitted for more detailed laboratory analysis (Table 2). The laboratory analyses were split into a topsoil characterisation suite and subsoil characterisation suite (Table 2), in line with the Draft Guidance – Material Characterisation Baseline Data Requirements for Mining Proposals (DMP 2016).

## 2.4 Soil classification systems

There are three systems of classification adopted for this project:

- Australian Soil Classification;
- Soil Groups of Western Australia; and
- Soil Mapping Units.

The Australian Soil Classification (ASC) is the national system for soil classification. The scheme defines soil classes on real soil bodies using a key. Classes are allocated based on diagnostic horizons and the arrangement of materials in a vertical sequence as seen in an exposed soil profile and accounting for geographic attributes of the landform.

The Soil Groups of Western Australia (SGWA) is a Western Australia-specific standardised method that provides common names to the main soils of the State. These soil groups were developed to assist with communicating information collected as part of land resource and rangeland mapping programs. Classes are allocated based on soil texture and depth.

The Soil Mapping Unit (SMU) is the basic geographic component of a soil map and can be associated with a single or multiple soil types with definable characteristics. SMUs are developed based on recurring landscape and soil attributes, with minor variations in soil properties allowable within each unit. The purpose of SMUs is to group soils by their management requirements (e.g. depth, salinity, sodicity).

**Table 1:** Soil analysis performed on all samples

| Analysis | |
|---|---|
| • Hand texture<br>• Fine/coarse fraction percentage<br>• Colour (Munsell) | • $pH_{1:5}$ ($H_2O$)<br>• $EC_{1:5}$<br>• Emerson dispersion |

**Table 2:** Soil laboratory analysis performed on a subset of samples

| Test Suite | Target samples | Analysis |
|---|---|---|
| Topsoil | 'A' horizon (topsoil) generally <100mm depth.<br><br>Analyses include chemical and physical properties of the soil, and soil fertility. This is the soil depth that contains the majority of fertility and is supporting the existing vegetation. | • $pH_{1:5}$ ($H_2O$)<br>• $EC_{1:5}$<br>• Total Cl<br>• Exchangeable cations (K, Ca, Mg, Na & Al)<br>• Effective cation exchange capacity (ECEC)<br>• Exchangeable sodium percentage (ESP)<br>• Particle size distribution of the fine fraction<br>• Organic Carbon<br>• Total N and Total P<br>• Available P and K (Colwell)<br>• Available Sulphur (KCl)<br>• Trace elements (Cu, Zn, Mn & Fe) |
| Subsoil | All other horizons below the topsoil (>100mm).<br><br>Analyses focus on chemical and physical properties of the soil, excluding fertility. | • $pH_{1:5}$ ($H_2O$)<br>• $EC_{1:5}$<br>• Total Cl<br>• Exchangeable cations (K, Ca, Mg, Na & Al)<br>• Effective cation exchange capacity (ECEC)<br>• Exchangeable sodium percentage (ESP)<br>• Particle size distribution of the fine fraction |

# 3 HAVERION LANDFORMS AND SOILS

The Atlas of Australian Soils (Northcote et al. 1968) includes broadscale mapping of the arid interior of WA. This mapping describes and groups land with a recurring pattern of topography, soils, and vegetation. Broad soil-landscape mapping of the arid interior was produced at a scale of 1:2,000,000. No other soils data are available for the project area.

The existing broad-scale mapping over the project area, including a description of the existing landform, is summarised in Table 3. Landforms consist of sandplains and dunes on sedimentary rocks of the Canning Basin. These areas are characterised by dune fields, with largely stable linear dune fields with swales opening locally into sand plains, with some pans and depressions and isolated residual sandstones. Typical soils are red deep sands and red sandy earths occurring on and in close proximity to the sand dunes, with some red loamy earths occurring within the interdune zones. Shallow gravels are present where rock is exposed. All soils are classified as Tenosols within the ASC.

**Table 3:** Existing broadscale mapping

| Land System | Chief Soil | ASC | Description |
|---|---|---|---|
| Fa32 | Shallow Stony Earthy Loams | Tenosol | Low ranges and hills largely on metamorphics and granites, but with some inclusions of sandstone and conglomerates. Extensive areas of bare rock transgressed by dunes in places and flanked by small plains. Chief soils are shallow stony earthy loams on hillslopes and other soils occurring on dunes. |
| AB40 | Red Earthy Sands | Tenosol | Gently undulating planes dominated by longitudinal dunes, many exposures of ironstone gravels, and some breakaways capped by ironstone duricrust. Chief soils are red earthy sands, with red siliceous sands on the dunes. |
| BB17 | Calcareous Loams | Tenosol | Uneven rough calcrete plains with small salt lakes and pans broken by variable proportions of longitudinal sand dunes and occasional low rises or hills. Chief soils are calcareous loams with some brown calcareous earths and red earthy sands. |

Although no land systems mapping is present over the Project area, the Little Sandy land system is located near to the project area. The geology of this land system is characterised by Quaternary eolian sands. Geomorphology includes depositional surfaces with sandplains and dune fields formed by wind action. Linear and reticulate dunes trend generally west-north west to east-south east, with sandplains and swales as corridors between the dunes. Minor gravelly plains and plains with thin sand cover occur over calcrete and isolated low hills. There are no organised drainage features but some low lying tracts that receive through flow. Dune relief can be up to 30m.

The three key landforms present in the Little Sandy land system are:

- Sandplains and swales that extend up to 5km, or as corridors between dunes;
- Linear sand dunes that extend up to 40km with moderately inclined slopes and uneven crest surfaces; and
- Gravelly plains with level to gently undulating plains extending for up to 2km, with sandy surfaces with mantles of common to abundant ironstone gravels.

Soils associated with the Little Sandy land system are similar to those noted in the broadscale mapping. That is, red deep sands on linear sand dunes, red deep sands and red sandy earths in swales, and shallow gravel soils on gravelly plains.

# 4 SOIL SURVEY

## 4.1 Field investigation

### *4.1.1 Soil descriptions*

The soil survey was conducted in June 2020. Soil description sheets for each of the 21 sites are provided in Appendix A. Soil orders identified by the ASC and GSG classification schemes are presented in Tables 4 and 5, respectively. A map of the ASC extent is provided in Figure 6 and 7 and the GSG extent in Figure 8 and 9.

**Table 4:** ASC classification of the soils within the Havieron project area and service corridor.

| Australian Soil Classification (ASC) | Description | Sites | Percentage of area (%) |
|---|---|---|---|
| Rudosol | Soils with negligible (rudimentary) pedological organisation apart from minimal development of an A horizon, or the presence of less than 10% of B horizon material in fissures. | TP04, TP05 TP06, TP09 TP11, TP12 TP14, TP15 TP16, TP18 TP19, TP20 | 59 |
| Kandosol | Gradational soils with massive or weakly structured B horizons (subsoils). The B horizon has a clay content that exceeds 15%. | TP01, TP02 TP03, TP07 TP08, TP10 TP13, TP17 TP21 | 41 |

**Table 5:** SGWA classification of the soils within the Havieron project area and service corridor.

| SGWA | Description | Sites | Percentage of area (%) |
|---|---|---|---|
| Red Deep Sand | Sands greater than 80cm deep. Red within surface 30cm. | TP04, TP05 TP06, TP09 TP11, TP12 TP14, TP15 TP16, TP19 TP20 | 58 |
| Red Sandy Earth | Soils with a sandy surface grading to loamy by 80cm. May be clayey at depth. Red within surface 30cm. | TP01, TP02 TP07, TP08 TP10, TP13 TP18, TP21 | 39 |
| Red Loamy Earth | Soils with a loamy surface and either loamy throughout or grading to clay by 80cm. Red within surface 30cm, massive or poorly structured, earthy fabric. | TP03, TP17 | 3 |
| Bare Rock | Rock outcrop | - | 0.2 |

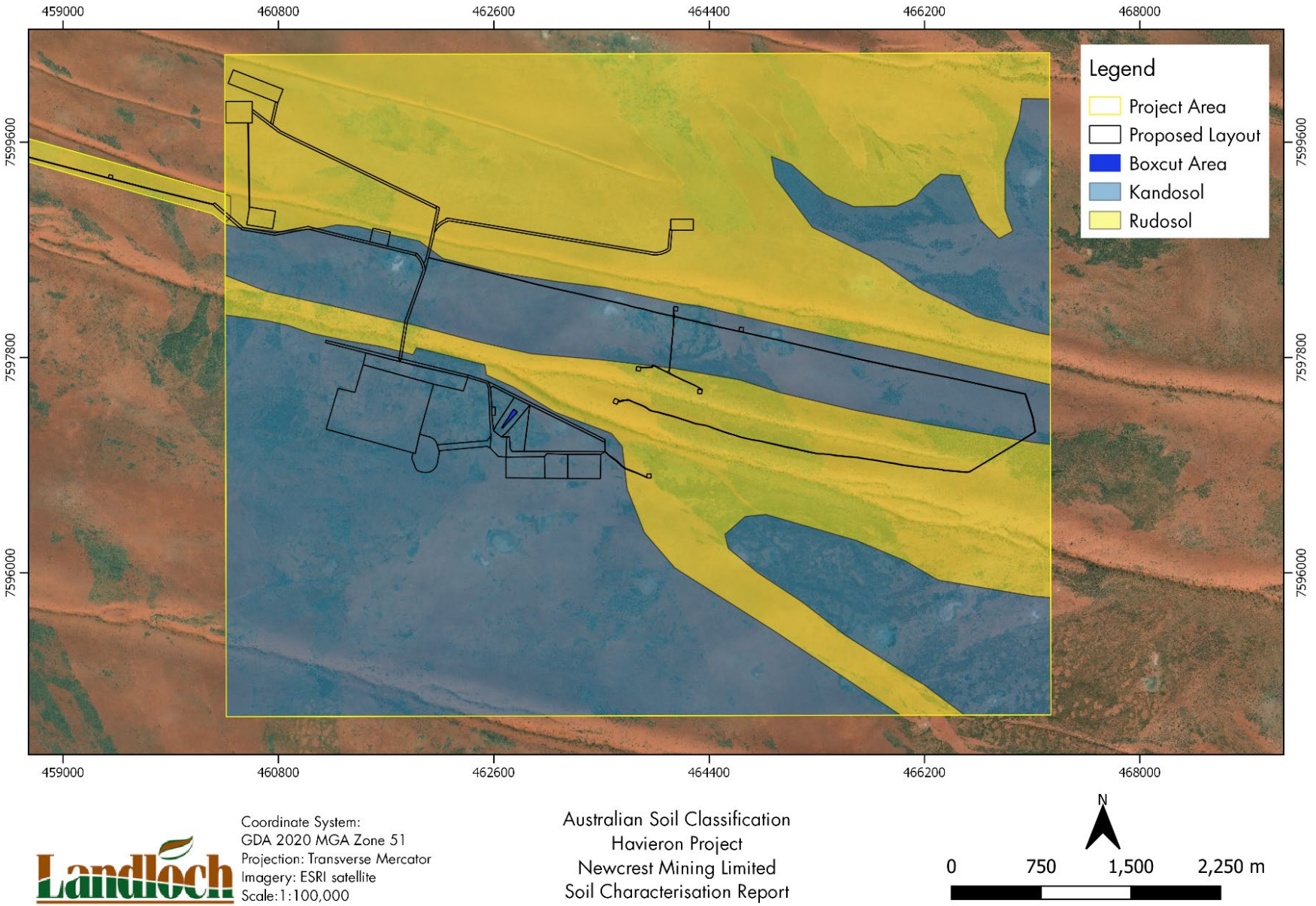



**Figure 6:** Australian Soil Classification of the Project area

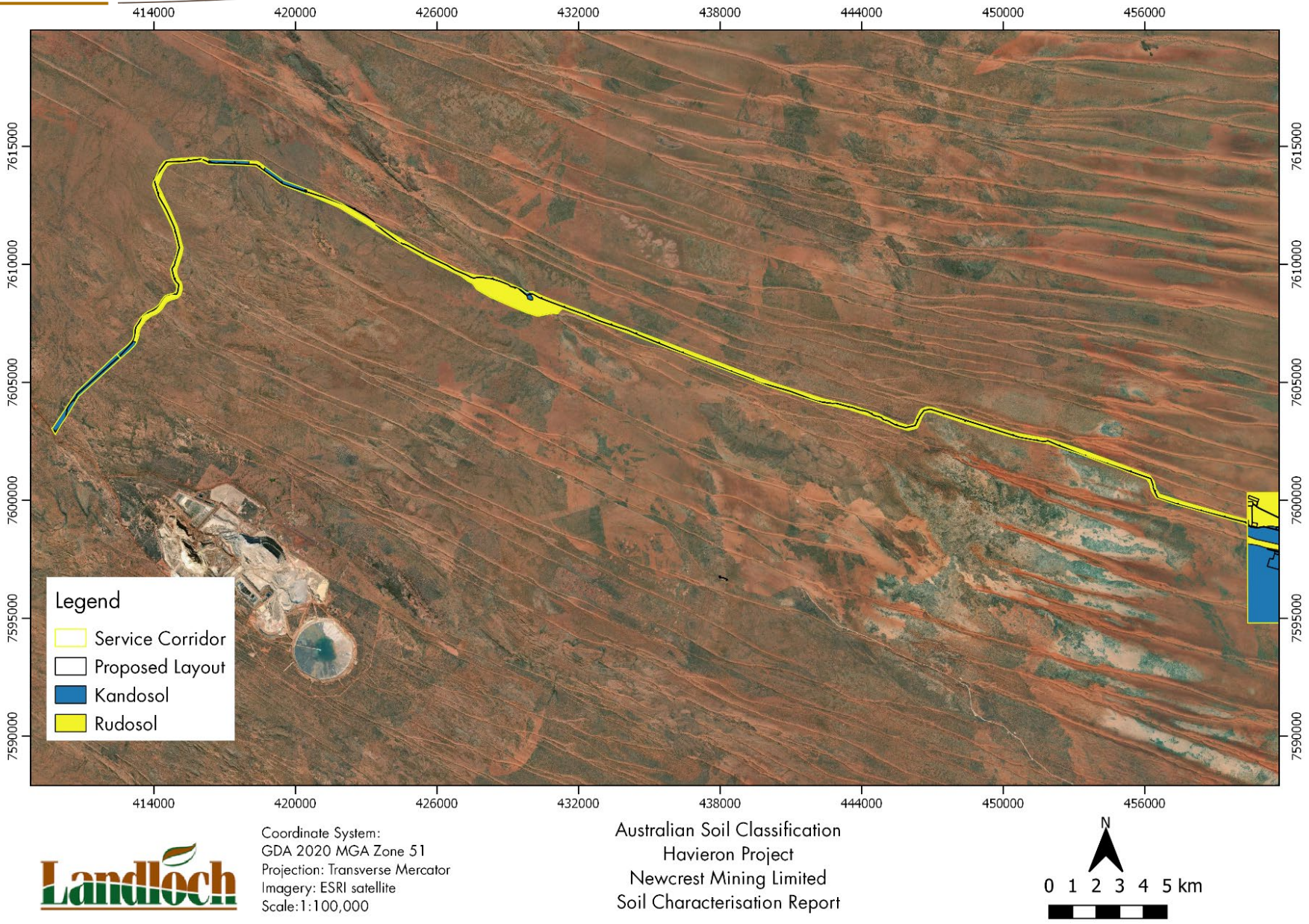



**Figure 7:** Australian Soil Classification of the service corridor

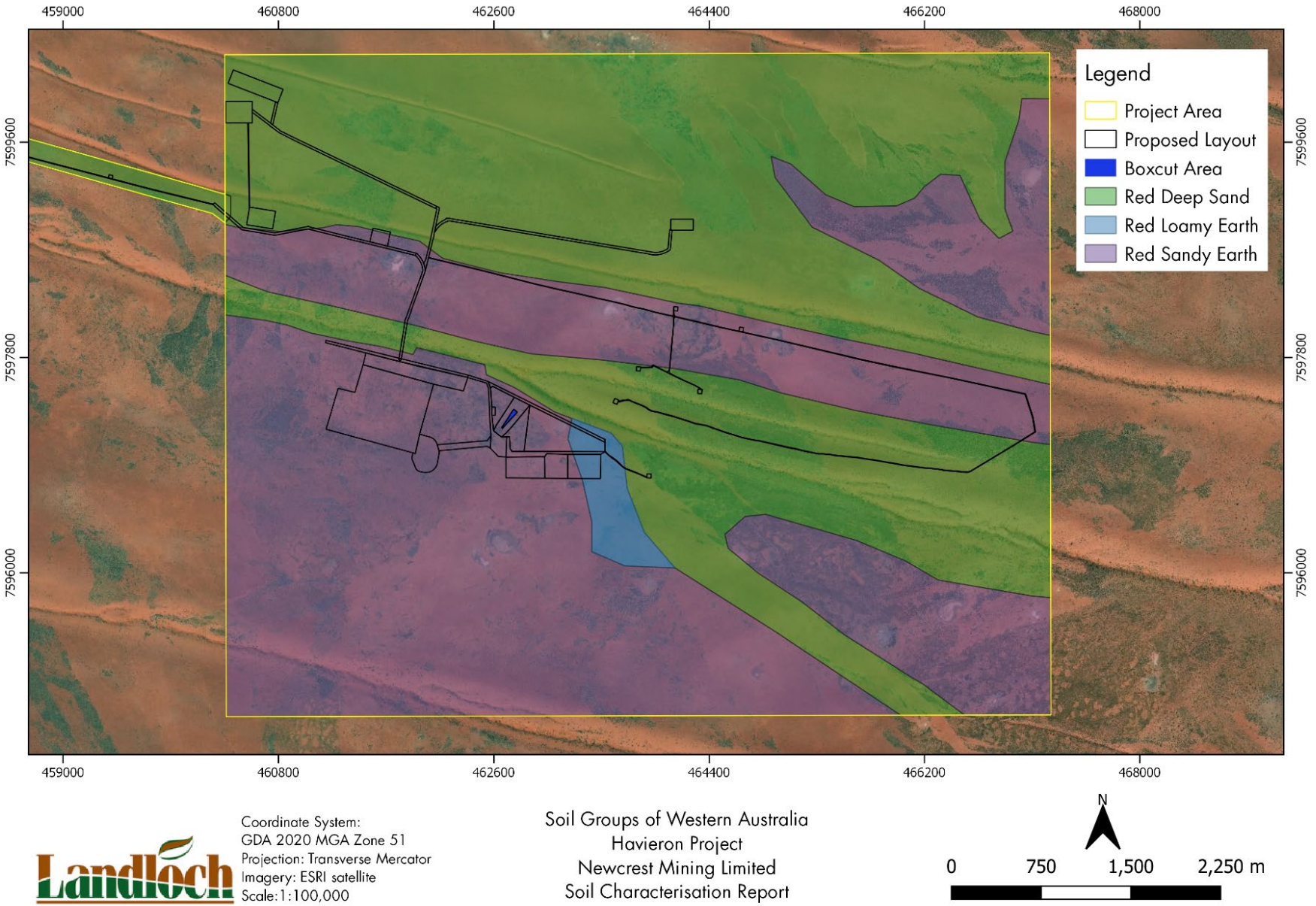



**Figure 8:** Soil Groups of Western Australia for the Project area

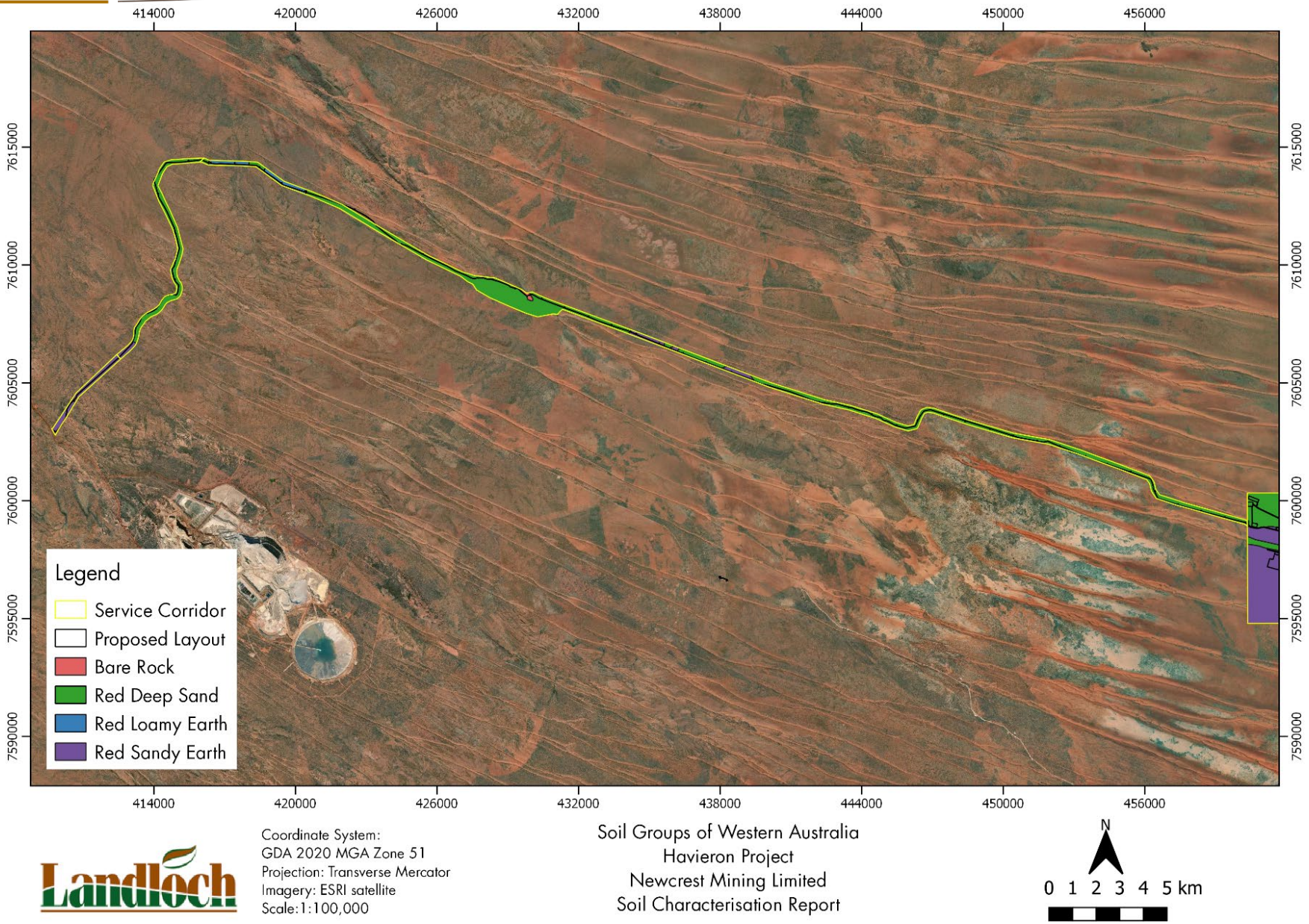



**Figure 9:** Soil Groups of Western Australia for the service corridor

### *4.1.2 Soil mapping units*

Three soil mapping units (SMUs) capture the variation in soils in the project area (Table 6 and Figure 10 and 11):

- Deep Sands are wind-blown aeolian sands associated with sand dunes present throughout the landscape. These soils are dominated by fine sands with no appreciable silt or clay and no pedological development.
- Gradational Loams are characterised by a thin layer of wind-blown aeolian sands that grade rapidly to sandy loam, with a gradual increase in clay content from clay loam to light clay at depth. The influence of wind-blown aeolian sands are less apparent in these soils. Included in this unit are:
    - Non-saline and non-sodic sub-unit (not saline or sodic)
    - Saline and sodic sub-unit (highly saline and sodic)
- Gradational Sands are similar to the Deep Sands, except for a change in texture from sand to loam in the deeper B horizon. These soils are characterised by a buried horizon at depth that represents the original soil profile that was covered in wind-blown aeolian sands.

Examples of a soil profile from each of the SMUs (Deep Sands, Gradational Sands and Gradational Loams) are provided below.

**Table 6:** Soil mapping units of the Project area

| SMU | Sub-SMU | Soil description | ASC | SGWA | % of area | Associated sites |
|---|---|---|---|---|---|---|
| Deep Sands | | Wind-blow aeolian dune sands with no pedological development | Rudosols | • Red Deep Sand | 53 | TP06, TP09 TP12, TP14 TP15, TP19 TP20 |
| Gradational Loams | Non-saline non-sodic | Sandy loams with a gradual increase in clay content at depth | Kandosols | • Red Sandy Earth • Red Loamy Earth | 2 | TP01, TP02 TP03, TP08 TP10, TP17 |
| | Saline Sodic | Sandy loams with increasing salinity and sodicity at depth | Kandosols | • Red Sandy Earth | 25 | TP13 |
| Gradational Sands | | Wind-blow aeolian dune sands overlying loams to light clays | Rudosols Kandosols | • Red Deep Sand • Red Sandy Earth | 20 | TP04, TP05 TP07, TP11 TP16, TP18 TP21 |

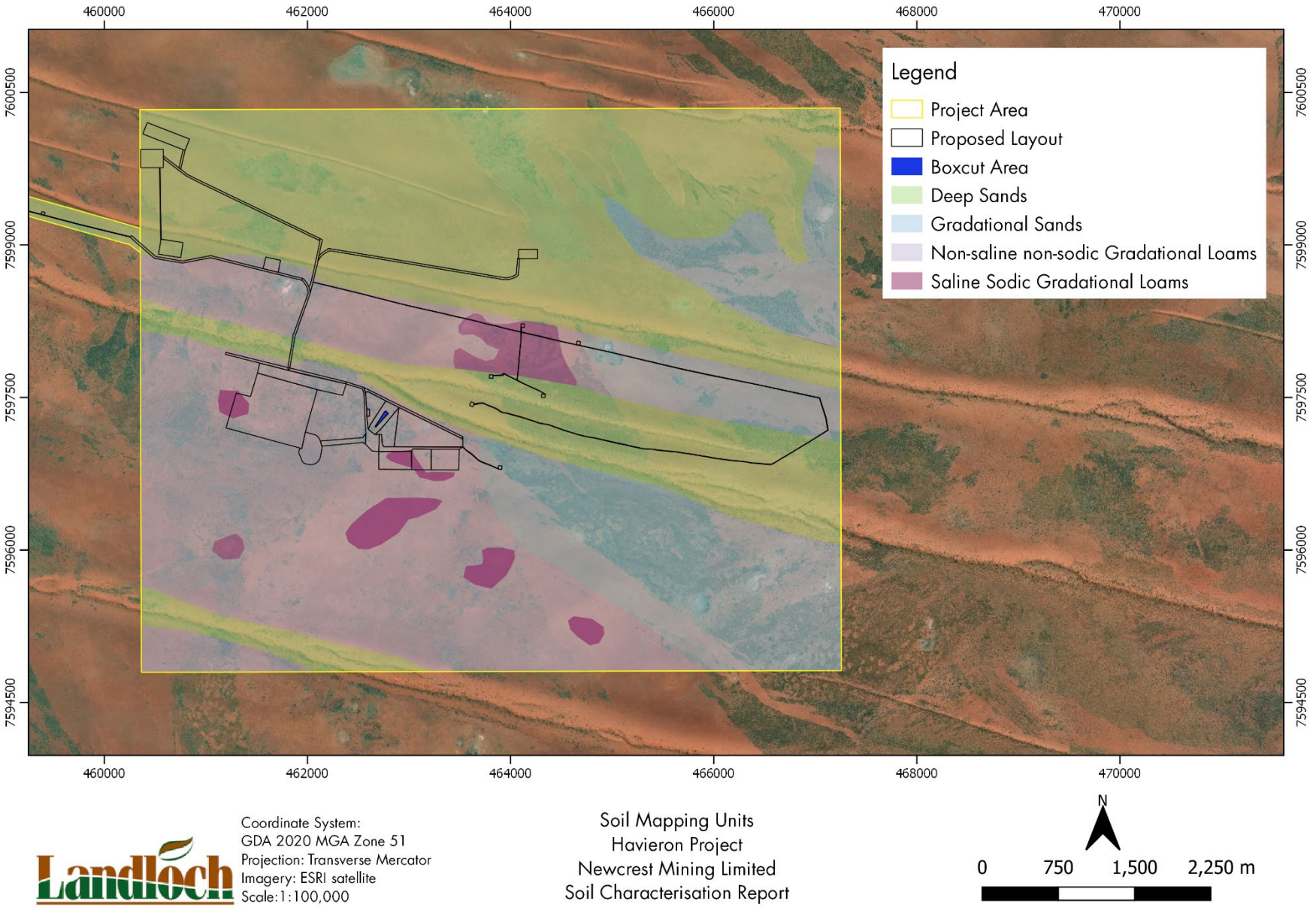



**Figure 10:** Soil Mapping Units of the Project area including the boxcut.

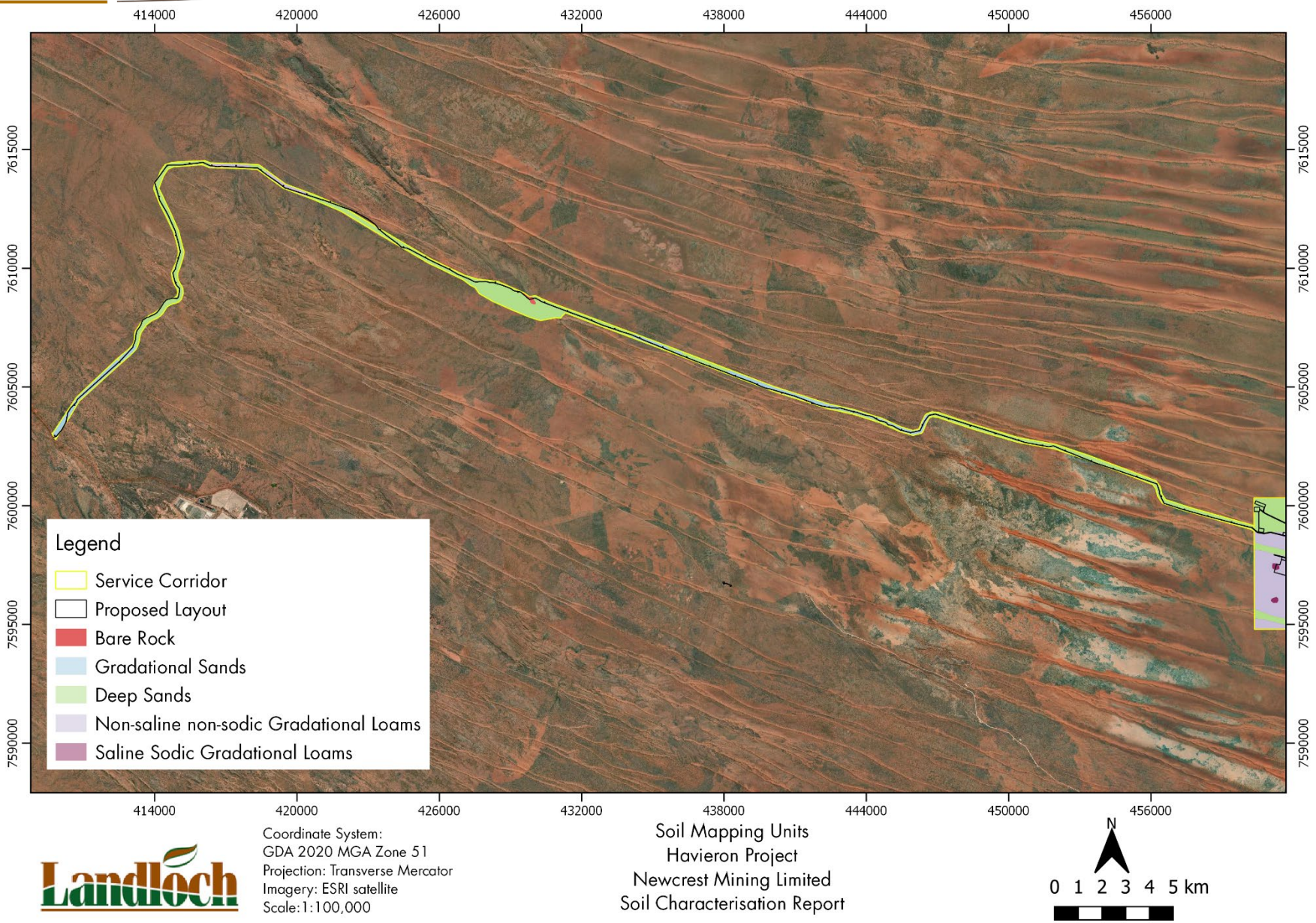



**Figure 11:** Soil Mapping Units of the Project area illustrating service corridor

# Soil Mapping Unit: Deep Sands

**Representative Site No:** TP15
**Landform:** Mid-slope
**Micro-relief:** None evident

**Dominant Vegetation:** Non-woody (Mid dense 30-70%), Woody (Sparse 10-30%)
**Surface condition:** Loose (dry)
**Surface cover:** None

**Site Drainage:** Well-drained
**Australian Soil Classification:** Rudosol

**General comments:** Deep sandy profile, little variation. No coarse fragments evident.

| Landscape Photos | Profile Photo | Horizon | Moist Colour | Texture | Structure | Consistence | Rooting depth | pH & EC |
|---|---|---|---|---|---|---|---|---|
|    |  | A (0-0.1m) Abrupt | 2.5YR 4/8 Red | Loamy sand | Granular (single grained) | Very weak (dry) | Common, fine roots | 7.0 0.0 dS/m |
| | | B (0.1-1.4m) | 2.5YR 4/8 Red | Loamy sand | Granular (single grained) | Very weak (dry) | Few, medium roots | 200-300mm: 7.0 0.014 dS/m 500-600mm: 7.0 0.009 dS/m 1100-1200mm: 6.5 0.017 dS/m |

## Soil Mapping Unit: Gradational Sands

**Representative Site No:** TP18

**Landform:** Lower slope

**Micro-relief:** None evident

**Surface condition:** Firm (dry)

**Dominant Vegetation:** Non-woody (Mid-dense 30-70%), Woody (Very sparse 0.2-10%)

**Surface cover:** 2-10mm 40% coarse frags.

**Site Drainage:** Moderately well-drained

**Australian Soil Classification:** Rudosol

**General comments:** Significant increase in gravels at 500mm depth. Gravels on the surface.

| Landscape Photos | Profile Photo | Horizon | Moist Colour | Texture | Structure | Consistence | Rooting depth | pH & EC |
|---|---|---|---|---|---|---|---|---|
|  |  | A (0-0.4m) Diffuse boundary | 2.5YR 3/6 Dark red | Clayey sand 20-50% coarse fragments 2-6mm in size | Angular blocky (moderate) | Weak (dry) | Common, medium roots | 0-100mm: 6.0 0.04 dS/m 200-300mm 5.9 0.001dS/m |
|  | | B21 (0.4-1.1m) Abrupt boundary | 2.5YR 4/8 Red | Clayey sand 50-90% coarse fragments 2-6mm in size | Granular (single grain) | Very weak (dry) | Few, fine roots | 6.3 0.01 dS/m |
|  | | B22 (1.1-1.2m) | 2.5YR 4/3 Reddish brown | Light clay 20-50% coarse fragments 2-6mm in size | Polyhedral (weak) | Firm (dry) | No roots | 6.8 0.01 dS/m |

## Soil Mapping Unit: Gradational Loams

**Representative Site No:** TP08

**Landform:** Flat

**Micro-relief:** None evident

**Dominant Vegetation:** Non-woody (Sparce 10-30%), Woody (Sparce 10-30%)

**Surface cover:** None evident

**Site Drainage:** Imperfectly drained

**Surface condition: Firm** (dry)

**Australian Soil Classification:** Kandosol

**General comments:** 2% Black gravel at >100mm depth.

| Landscape Photos | Profile Photo | Horizon | Moist Colour | Texture | Structure | Consistence | Rooting depth | pH & EC |
|---|---|---|---|---|---|---|---|---|
|  |  | A (0-0.1m) Abrupt boundary | 2.5YR 3/6 Dark red | Loamy sand | Polyhedral (Weak) | Weak (dry) | Few, fine roots | 7.0 0.028 dS/m |
|  | | B1 (0.1-0.45m) Abrupt boundary | 2.5YR 4/6 Red | Clay loam | Polyhedral (Weak) | Firm (dry) | Few, fine roots | 7.0 0.092 dS/m |
|  | | B2 (0.45-0.9m) | 2.5YR 4/8 Red | Light - medium clay | Subangular blocky (Weak) | Strong (dry) | None evident | 500-600mm: 7.5 3.61 dS/m 700-800mm 8.0 0.78 dS/m |

# 5 SOIL MAPPING UNIT CHARACTERISTICS

## 5.1 Deep Sands

The typical characteristics of the Deep Sands are:

- Loamy sand to clayey sand texture throughout the profile;
- Single grained (no structure);
- Weak consistency to firm at depth;
- Roots commonly present in the A horizon, decreasing in abundance with depth;
- Slightly acidic to circum-neutral throughout the profile;
- Non-saline and non-sodic;
- Low fertility in the topsoil; and
- Low capacity to hold nutrients.

The Deep Sands occur within the interdune and dune zone of the landscape. The key defining attributes of the Deep Sands is their consistent texture throughout the profile, with no appreciable clay and no pedological development (Table 7).

**Table 7:** Typical characteristics of Deep Sands baseline material characterisation. Values in brackets represent average.

| Characteristics | Topsoil | Subsoil |
|---|---|---|
| Horizon | A1 | B1 |
| Depth (mm) | 0-100 | 100-1200 |
| Texture | Loamy sand | Loamy sand - clayey sand |
| Structure | Single grain | Single grain |
| Consistency | Very weak (dry) | Very weak - firm (dry) |
| Coarse fragments | None evident | None evident |
| pH | 5.5 - 7.0 (6.4) | 5.5 - 7.0 (6.3) |
| Salinity (dS/m) | <0.1 | <0.1 |
| Sodicity (ESP) % | 5.7 | 4.5 – 6.5 (5.3) |
| Emerson Class | 5 - 6 | 5 - 6 |
| Fertility | Low | - |

## 5.2 Gradational Sands

The typical characteristics of the Gradational Sands are:

- Loamy sand to clayey sand texture through the majority of the profile, with an increase in clay content at ~1m to a loam/sandy clay loam (indicative of a buried horizon);
- No structure (Apedal and single grained);
- Roots present in the A and B2 horizons, decreasing in abundance with depth;
- Non-saline and but can be sodic;
- Low fertility in the topsoil.

The Gradational Sands occur within the interdune zone of the landscape. The key defining attribute of the Gradational Sands is sandy soils grading to sandy loams to clay loams at depth (Table 8).

**Table 8:** Typical characteristics of Gradational Sands baseline material characterisation. Values in brackets represent average.

| Characteristics | Topsoil | Subsoil | |
|---|---|---|---|
| Horizon | A1 | B2 | 2B (Buried horizon) |
| Depth (mm) | 0-150 | 150-1000 | 1000-1250 |
| Texture | Loamy sand | Loamy sand - Clayey sand | Sandy loam - Light clay |
| Structure | Single grain - Weak | Single grain | Single grain - massive |
| Consistency | Weak (dry) | Firm (dry) | Firm - Very firm (dry) |
| Coarse fragments | None evident - 2-6mm (10%) | None evident - 2-6mm (10%) | None evident - 2-6mm (20-50%) |
| pH | 6.0 - 8.0 (6.7) | 6.3 - 8.0 (6.9) | 6.1 - 7.1 (6.7) |
| Salinity (dS/m) | <0.1 | <0.1 - 0.5 | <0.1 - 0.2 |
| Sodicity (ESP) % | 5.7 - 16.4 (10.6) | 5.0 - 7.9 (6.3) | 4.5 - 8.2 (6.0) |
| Emerson Class | 3 - 6 | 5 - 6 | 5 - 6 |
| Fertility | Low | - | - |

## 5.3 Gradational Loams

The Gradational Loams are split into two sub-classes:

- Non-saline and non-sodic; and
- Saline and sodic.

The typical characteristics of the non-saline and non-sodic Gradational Loams are:

- Loamy sand A horizon overlying sandy clay loam to light clay B horizons;
- No structure (Apedal and single grained/massive);
- Rooting depth generally limited to the A1 and B2 horizons;
- Generally circum-neutral pH;
- Non-saline and non-sodic
- Slightly to moderately sodic; and
- Low fertility in the topsoils.

The typical characteristics of the saline and sodic Gradational Loams are:

- As per the above characteristics with the exception of high salinity and sodicity at 200mm onwards. These soils are located in lower landscape positions and near dry lakes.

The Gradational Loams occur within the interdune zone of the landscape. These soils can be highly saline near dry lakes. The key defining attributes of the Gradational Loams are the loamy topsoil grading to light clay textures at depth (Table 9).

**Table 9:** Typical characteristics of Gradational Loams baseline material characterisation. Values in brackets represent average.

| Characteristics | Topsoil | Subsoil | |
|---|---|---|---|
| Horizon | A1 | B21 | B22 |
| Depth (mm) | 0-100 | 100-600 | 600-1400 |
| Texture | Loamy sand | Sandy clay loam | Sandy clay loam – light medium clay |
| Structure | Single grain - weak | Single grain - weak | Single grain - massive |
| Consistency | Weak - very weak (dry) | Weak - very firm (dry) | Firm - strong (dry) |
| Coarse fragments | None evident - 10-20mm (~80%) | None evident - 2-6mm (~6%) | None evident - 2-6mm (50-90%) |
| pH | 6.0 - 7.0 (6.2) | 6.0 – 7.7 (6.8) | 6.3 – 7.9 (7.2) |
| Salinity (dS/m) | <0.1 – 0.3 (<0.1) | <0.1 – 4.4 (0.9) | <0.1 – 3.0 (3.4) |
| Sodicity (ESP) % | 11-15 (13) | 9 - 26 (15) | 8 - 28 (18) |
| Dispersity | 6 | 5 - 6 | 5 – 6 |
| Fertility | Low | Low | Low |

# 6 SOIL MANAGEMENT

## 6.1 Wind erosion

No qualitative wind erosion modelling was undertaken. However, based on the soil characterisation data for Havieron, and experience on other sites with aeolian sands, it is likely that wind erosion will be of concern for the Deep Sands and Gradational Sands. In particular, the surface sands that have low clay contents.

Wind is of potential importance at Havieron because of the presence of aeolian sand dunes that are essentially wind-blown deposits. Dunes at Havieron are linear in shape and are likely to have been formed in circumstances where there are two converging dominant wind directions (Figure 12). Where only one direction is dominant, singular, large dunes are typically formed, and where there is no dominant wind, complex pyramidal shaped dunes are formed.

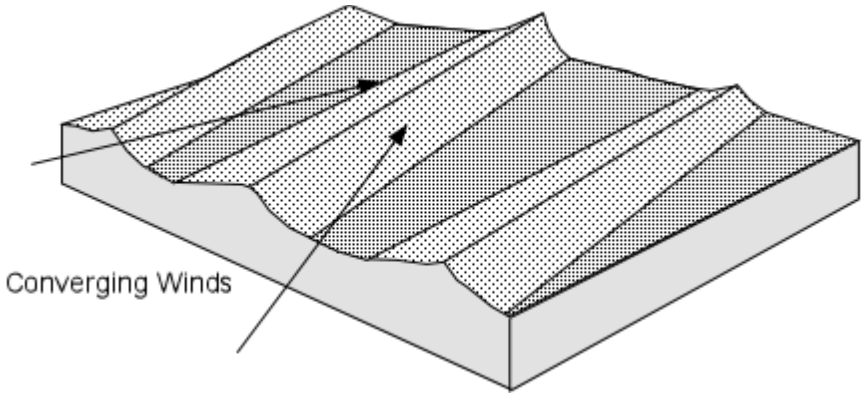



**Figure 12:** Formation of linear dunes from two converging wind directions (www.tulane.edu/~sanelson/geol111/deserts.htm)

Bagnold (1941) reports that linear dunes to not necessarily move laterally for any great distance, and can grow in size while remaining immobile. This occurs when the dune is essentially symmetrical in cross section, with winds from one direction moving sand to the dune, and winds from the other direction effectively moving sands along the dune, causing it to elongate. The growth of such dunes is ultimately limited by sand supply. Vegetation on these dunes may have developed as a result of a lack of supply of 'new' sand, or due to a change in wind direction after the dunes were established. Linear dunes can be many kilometres long and may be discontinuous.

Particle size data for the Deep Sands indicate these soils generally contain ~10% clay, ~2% silt and ~40% fine sand with ~48% coarse sand. The Gradational Sands exhibit a similar particle size in the top 800mm, with an increase in at depth. The Gradational Loams contain up to 20% clay throughout the profile. This indicates that the Deep Sands and Gradational Sands may be prone to wind erosion.

Particle size results similar to the surface sands have been recorded for Nifty, where sand dunes are disturbed as part of mining. At Nifty, the sand sampled by Landloch consist of ~2% clay, <1% silt, 40% fine sands and ~58% coarse sands. Sands within the dunes at Nifty were observed to remain quite sandy to significant depths (Figure 13).

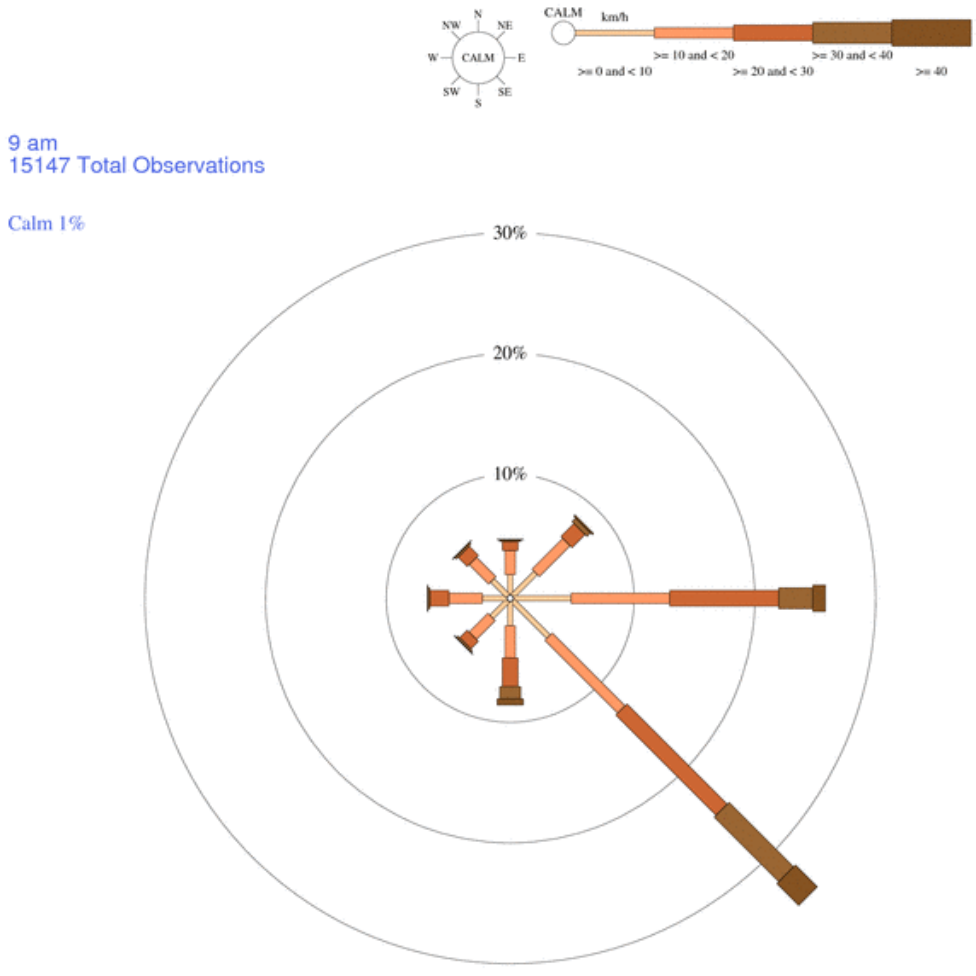

**Figure 13:** Sandy textures occurring within sand dunes at Nifty.

Landloch also previously sampled dune sands from the Tropicana Gold Project as part of their approvals process (Landloch 2009). These sandy soils contained ~12% clay, ~1% silt, ~30% fine sand, and ~55% coarse sand. A soil taken from deeper in the profile (>0.5m) had a higher clay content (19%) and a lower fine and coarse content. This is similar to the Gradational Loams.

Sand samples from Tropicana and Nifty were further analysed to determine their modal particle size as a way to consider wind erosion risk. The model size of the Tropicana dune sands was 0.45mm. The model size for the Nifty sands was 0.28mm. For Nifty and Tropicana, 50-75% of the sands fall within the size range of 0.15-0.5mm. FAO (1985) reports that grain sizes within this range are usually involved in saltation and are commonly found in wind-blown deposits. Therefore, assuming that the Deep Sands and

Gradational Sands are similar to other aeolian sands, it is concluded that these soils are potentially prone to wind erosion. The deeper, loamy materials within the Gradational Sands, and the soils of the Gradational Loams may be less prone to wind erosion as aggregation may contribute to them being less mobile.

The risk of wind erosion also relates to the direction of prevailing winds and the typical wind speeds. Wind data for Telfer provides observed range of wind speeds and directions. This data is given in Figure 14.




Australian Government
Bureau of Meteorology

**Figure 14:** Wind rose data for Telfer from 1974 to 2016.

The wind direction is generally from south-east to north-west, which generally aligns with the orientation of the linear dunes. As such, it can be inferred that the wind direction has a controlling influence on the orientation of the dunes. Wind speeds are generally >20km/h, and can be as high as >40km/h. Winds greater than ~30km/h are typically

required to move soil particles and lift dust over significant distances. Winds with speeds as low as 2km/h can cause localised erosion of unvegetated sandy surfaces. As such, the winds at Havieron could potentially cause erosion of the surface sands.

As part of mining, these sandy surfaces will be disturbed and vegetation will be removed. Then as part of rehabilitation it is likely that these sands will be considered as a growth media to sheet constructed landforms. The removal of vegetation can greatly increase the risk of wind erosion, and significant damage can be done by wind in relatively short periods of time. Good quality grasslands with >40% vegetation cover (which are present over some areas at Havieron) are unlikely to be prone to excessive wind erosion. However, as cover levels decrease – as will be the case in the early stages of landform rehabilitation, or where vegetation fails to establish – the risk of wind erosion greatly increases (FAO 2019). It is estimated that a reduction in cover level to <10% could increase erosion potential by more than one order of magnitude.

### *6.1.1 Management of wind erosion*

Wind erosion at Havieron is currently limited by the erosion resistance provided by vegetation. The existing dunes are orientated in a north-east to south-west direction in a similar direction to the prevailing winds. This orientation limits the movement of sand to within the dune area itself, and is not likely to cause lateral migration of the crest of the dunes.

If the Deep Sands and Gradational Sands are disturbed and placed in a landform orientated perpendicular (running north-south) to the current prevailing wind, the risk of wind erosion (to effectively cause dune migration) increases, and successful revegetation of the highly erodible crest of the landform will be particularly difficult. Orienting the landform in an east-west direction would be desirable if practicable.

If this orientation is not possible, armouring of the windward side (and particularly the crest) will be required. This will be necessary until vegetation is established and able to provide surface erosion resistance. Without intervention, unvegetated sand susceptible to wind erosion cannot be expected to revegetate due to:

- Injury of seedlings due to abrasive action of blowing sands;
- Exposure of newly developed root systems as sand moves; and
- Young seedlings being buried by sand.

Increased surface resistance can be achieved by:

- Placement of vegetative debris on the surface;
- Placement of gravel and/or rock on the surface; and/or
- Application of temporary surface treatments (adhesives).

Ideally, if rock or vegetation debris is to be used, it should be applied to the entire slope. Chepil *et al.* (1963) found that rock need not be larger than approximately 5-10mm in diameter to be effective in limiting wind erosion. Approximately 20-40% of the soil surface should be covered. This is similar (though slightly lower) to the foliar cover required from vegetation to produce effective protection against wind (Carter 2002). If

supply of rock or vegetation debris is limited and these rates of surface coverage cannot be achieved, preference should be given to placement of these materials on the:

- Crest of the dune where turbulent wind flows tend to increase erosion; and
- Windward side where the largest wind force is experienced.

Additionally, the incorporation of clays into the surface layers can improve aggregation, increase the effective particle size and increase erosion resistance. Incorporation of 2-4t/ha of clay (to a depth of 25mm) has been shown to greatly reduce wind erosion on sandy loam soils (Hsieh and Wildung 1969). The clays present in the subsoil of the Gradational Loams may be potentially useful for this purpose.

## 6.2 Water erosion

The Deep Sands and Gradational sands are characterised by sandy, cohesionless soils. These soils are likely to be highly susceptible to water erosion when runoff occurs. Landloch has conducted several erosion assessments for soils with similar particle size distributions to the Deep Sands and Gradational Sands. Generally, soils with a very high abundance of coarse and fine sand sized particles are highly permeable. However, when rainfall is sufficient to generate runoff, erosion rates are generally very high.

The Deep Sands and Gradational Sands are likely to be prone to water erosion when placed on landforms, even with relatively low batter heights and shallow angles. Previous testing of similar materials indicates that dune sands will generally erode at rates such that they are prone to rilling even when placed on relatively low embankments (<10m). As such, there are likely to be serious practical impediments to successful rehabilitation of long slopes with the sands. Given this, the Deep Sands and Gradational Sands should only be used on shallow, short slopes. Placement of these soils on landform shapes that encourage the concentration of flows will likely be at a higher risk of the development of rill and gully erosion. Additionally, placement of these soils on benches or overlying dispersive wastes may also result in significant erosion.

The Non-saline and Non-sodic Gradational Loams have a higher clay content which reduces their permeability when compared to the Deep Sands and Gradational Sands. These soils are less prone to detachment when exposed to runoff but will be more susceptible to erosion under intense storm events due to their lower permeability. The soils would benefit from the addition of a rock armour or tree debris to reduce the impact of overland flows on the sandy materials if used on batter slopes.

The Saline and Sodic Gradational Loams should not be used due to the risk of dispersion.

## 6.3 Growth media and stripping

The Deep Sands have few limitations from a growth media perspective. They are generally non-saline, non-sodic, slightly acidic to circum-neutral. However, the dominance of the sand fraction and lack of appreciable clay indicates a limited capacity to store water for plant growth, and a low capacity to hold and retain nutrients. As such, use of the Deep Sands for rehabilitation may be limited by their physical properties.

Establishment of vegetation or application of rock armour may assist in limiting the impact of wind and water erosion.

There are no limitations to the stripping depth of the Deep Sands. These soils can be stripped to any depth, provided that they are managed appropriately when stockpiled and when used as a growth medium for rehabilitation. For the purposes of this report, it is assumed that the topsoils will be stripped to 100mm.

The Gradational Sands are very similar to the Deep Sands in terms of their characteristics when stripped. The key characteristic of the Gradational Sands is the change in texture at 1m. Given that stripping is unlikely to occur to this depth, the Gradational Sands should be managed as per the Deep Sands; that is, topsoils stripped to 100mm.

The Non-saline non-sodic Gradational Loams have few limitations from a growth media perspective. This soil type is non-saline, non-sodic, and are suitable for stripping. The Saline Sodic Gradational soils are highly saline and sodic soils occurring in lower sections of the landscape and in proximity to dry lakes. These soils should not be stripped, as the high salinity and sodicity is likely to be a limiting factor for their use in rehabilitation.

The Non-sodic and Non-saline Gradational Loams have a higher abundance of clay in the subsoil, increasing their capacity to store and retain water for plant use. Stripping of the sandy topsoils should occur to 100mm, and stripping of the clayey subsoils to 400mm, with a total stripping depth of 500mm assumed. Subsoil stripping will only occur in the area of the boxcut. It is assumed that the Saline and Sodic Gradational Loams will not be stripped and have been excluded.

Volumes of potential soil to be stockpiled are provided for the boxcut and, the proposed infrastructure areas and WRD. The estimated volume of soil resources available over the boxcut area is provided in Table 10 below.

**Table 10:** Volume of available topsoil and subsoil for the Project area.

| SMU | Deep Sands | Gradational Sands | Gradational Loams (Non-saline & Non-sodic) | Total Volume ($m^3$) |
|---|---|---|---|---|
| **Proposed boxcut disturbance area** | | | | |
| Topsoil ($m^3$) | - | - | 443 | **443** |
| Subsoil ($m^3$) | - | - | 1,774 | **1,774** |
| **Proposed infrastructure and WRD disturbance areas** | | | | |
| Topsoil ($m^3$) | 27,185 | 1,298 | 112,674 | **147,618** |
| | | | **Total topsoil ($m^3$)** | **148,062** |
| | | | **Total subsoil ($m^3$)** | **1,774** |

## 6.4 Stockpiling

It is commonly recommended that stockpiles should be no deeper than 2.0m. It is generally considered that stockpiling topsoils deeper than 2.0m can deplete the topsoil seed bank and degrade the structure of the soil at the bottom of the stockpile. The key risk to consider when stockpiling these soils is wind erosion. Both these soil types are susceptible to wind erosion and will require management to reduce this risk. Limiting the height of the stockpiles to 2.0m should reduce the risk of wind erosion. Additionally,

application of surface treatments (e.g. surface tackifier or cover) should be considered to further reduce the wind erosion risk. As the Gradational Loams are less prone to wind erosion, stockpile depths up to 4.0m could be considered for this soil type.

If soils are to be stockpiled for longer than 12 months, they should be actively fertilised and seeded to:

- Reduce water and wind erosion risk;
- Maintain and accumulate soil organic matter levels; and
- Increase soil seed banks.

Fertiliser application rates for stockpiles should be determined based on the results of field trails. The species seeded should be fast growing, and ideally leguminous to provide some nitrogen input to the soil, though care should be taken to avoid introducing weeds. The low fertility of the available soils however may limit species selection to the locally adapted communities.

For best preservation of the soil seed bank and biota, the stockpiles should be flat-topped or slightly domed. Encouraging water entry will make more water available to plants and minimise the risk of erosion and sediment movement from the stockpile.

All stockpiles should be monitored for erosion (wind and water) and weed infestations. Control of weeds in stockpiled soil is likely to be more cost effective than controlling infestations once the soil is respread. Weeds can be controlled by planting species that will outcompete the weeds, or by spraying herbicides.

### 6.5 Respreading

Once the soil has been respread and directly prior to seeding, the final topsoil surface will require light ripping to break any surface crusting. Landloch has observed surface sealing greatly impacts on germination rates, and a site-specific seeding strategy should be developed based on field trial results using the specific rehabilitation material.

The precise rereading strategy will be determined by the requirements of the landforms. It is likely that the topsoil will require incorporation of rockier materials (wastes) to ensure erosional stability. In this situation this may require mixing using a dozer, either by pushing down rock and soil from the crest of the batter, or by spreading a layer of soil over a layer of waste rock and contour ripping to mix.

## 7 SOIL AMENDMENTS

The nutrient status of the soils across the project area is low, however, native vegetation is adapted to grow in this environment. For rehabilitation it is recommended to replace or supplement nutrients lost through disturbance to encourage rapid establishment of vegetation.

The precise nature of these nutrient additions will be in part determined by the success of the soil stockpiling strategies outlined above. If done successfully, the topsoil can be spread containing a seed bank of the target species and adequate nutritional levels to ensure good germination and growth. Soil stockpile monitoring (soil characterisation)

before spreading should be undertaken to determine the nutrient status of the materials. Levels should be at least comparable to those found in the undisturbed soils within this report.

Application of fertiliser to the topsoil is recommended based on the loss of nutrients caused by the removal of vegetation, disturbance of the soil, and the likely respreading in a thin layer of less fertile waste materials. Likely fertiliser requirements are not high and as an example, Landloch has seen success in arid zone rehabilitation at application rates in the order of 10-30kg/ha of both N and P and 3-8kg/ha of S. These could be supplied through the application of 40-80kg/ha of mono-ammonium phosphate and 15-30kg/ha of ammonium sulphate. This fertiliser application rate can be applied to all soil types and is calculated assuming a soil depth of 0.3m.

It should be noted that application of an immobile element such as P to the surface of soils that are high in iron oxide may not be successful, as the P is likely to be immobilised in the shallow surface layer and would therefore seldom be accessible to plant roots. Therefore, incorporation of fertiliser into the soil profile rather than application to the surface is strongly recommended.

## REFERENCES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# APPENDIX A – SOIL LOGS

# Site Information

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP01 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** | | | **Ground Cover %** | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Moderately well-drained | **Erosion Extent** Moderate | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

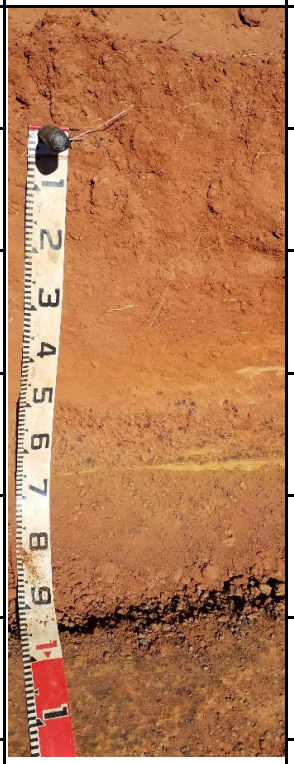
**Other Information:** 2-10mm coarse fragments on surface 40%

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | 2-10 %<br>2-6 mm | Apedal | Single grain | Very weak (dry) | Common (10-25)<br>Fine (1-2 mm) | 6.0 | 0.011 | 0-100 |
| B21 | 100-550 | | Clear | Loam | 2.5YR 3/6 Dark red | None evident | None evident | 2-10 %<br>2-6 mm | Apedal | Single grain | Weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 7.0 | 0.025 | 200-300 |
| B22 | 550-700 | | N/A | Sandy Clay Loam | 2.5YR 3/6 Dark red | None evident | None evident | 50-90 %<br>2-6 mm | Apedal | Single grain | Firm (dry) | No roots (0) | 7.0 | 0.023 | 500-600 |
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**Other information:** Compacted gravels with clay at 600mm, pea sized. Sands in top of horizon, increasing clay content at depth. Top horizon likely blown in (wind erosion). Aeolian sands over Kandosol. Bottom horizon likely formed from bioturbation.

# Soil Profile Description

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP02 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** | | | **Ground Cover %** | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Rapidly drained | **Erosion Extent** Moderate | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Firm | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Surface crust 2mm thick in some areas, not present across entire site.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 4/6 Red | None evident | None evident | None evident | Apedal | Single grain | Weak (dry) | Common (10-25) Fine (1-2 mm) | 6.1 | 0.020 | 0-100 |
| B21 | 100-900 | | Abrupt | Sandy Loam | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Very firm (dry) | Few (1-10) Fine (1-2 mm) | 5.5 5.7 | 0.030 0.020 | 200-300 500-600 |
| B22 | 900-1150 | | N/A | Sandy Clay Loam | 2.5YR 3/4 Dark reddish brown | None evident | None evident | None evident | Apedal | Single grain | Strong (dry) | No roots (0) | 6.3 | 0.040 | 900-1000 |
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**Other information:** Hard clay at bottom of profile, no coarse fragments in profile. Texture increases with depth.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP03 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | **Drainage (site)** Imperfectly drained | **Erosion Extent** None evident | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Gravel on surface 2-10mm 20%, some evidence of clay on the surface.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Sandy Clay Loam | 2.5YR 4/4 Reddish brown | None evident | None evident | 2-10 %<br>2-6 mm | Polyhedral | Weak | Weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.0 | 0.026 | 0-100 |
| B21 | 100-400 | | Abrupt | Sandy Clay Loam | 5YR 4/4 Reddish brown | None evident | None evident | 2-10 %<br>2-6 mm | Polyhedral | Weak | Firm (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.5 | 0.021 | 200-300 |
| B22 | 400-1200 | | N/A | Light Medium Clay | 5YR 4/4 Reddish brown | Blue 5% Red 5% | None evident | 2-10 %<br>2-6 mm | Apedal | Massive | Strong (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.5<br>7.0 | 0.016<br>0.018 | 500-600<br>800-900 |
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**Other information:** Massive clay from 400mm onward.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP04 | **Observation** Soil pit | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Aspect** | | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Slope %** | | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Well-drained | **Erosion Extent** Moderate | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Soft | | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

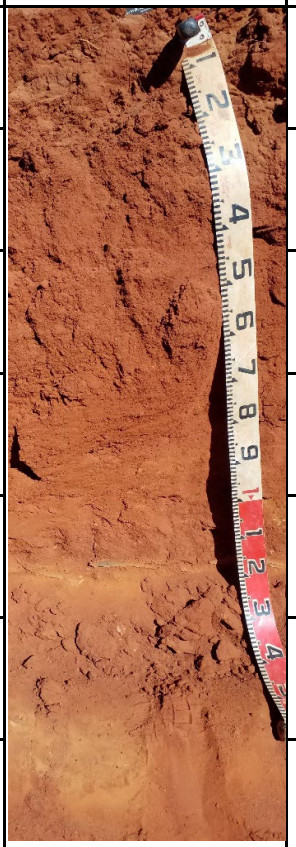
**Other Information:** Wind blown sands on surface.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-200 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Weak (dry) | Few (1-10) Fine (1-2 mm) | 6.5 | 0.016 | 0-100 |
| B | 200-1000 | | Abrupt | Clayey Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Firm (dry) | Few (1-10) Fine (1-2 mm) | 6.5 7.0 | 0.014 0.018 | 200-300 600-700 |
| 2B | 1000-1200 | | N/A | Sandy Loam | 2.5YR 3/6 Dark red | Cream 5% | None evident | None evident | Apedal | Single grain | Very firm (dry) | No roots (0) | 7.0 | 0.016 | 1000-1100 |
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**Other information: T**ypical sands, slight clay increase at depth**.** Arenic Rudosol.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP05 | **Observation** Soil pit | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Moderately well-drained | **Erosion Extent** None evident | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Firm | | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

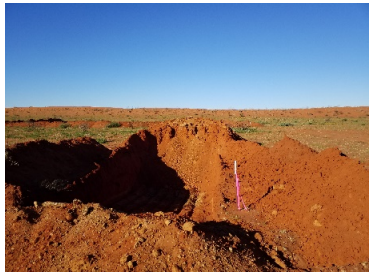
**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**



**Other Photo**

**Other Information:** Very small rocks on surface, less than 2mm, 50%. Thin surface crust 1mm thick.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-50 |  | abrupt | Loamy Sand | 2.5YR 4/6 Red | None evident | None evident | 2-10 %<br>2-6 mm | Apedal | Single grain | Weak (dry) | Common (10-25)<br>Fine (1-2 mm) | 6.5 | 0.010 | 0-100 |
| B21 | 50-900 | | Clear | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | 2-10 %<br>2-6 mm | Apedal | Single grain | Firm (dry) | Common (10-25)<br>Fine (1-2 mm) | 6.0<br>6.0 | 0.013<br>0.018 | 200-300<br>500-600 |
| B22 | 900-1000 | | Abrupt | Clayey Sand | 2.5YR 3/6 Dark red | None evident | None evident | 2-10 %<br>2-6 mm | Apedal | Single grain | Firm (dry) | No roots (0) | 6.5 | 0.015 | 900-1000 |
| 2B | 1000-1300 | | N/A | Sandy Clay Loam | 2.5YR 3/6 Dark red | None evident | None evident | 20-50 %<br>2-6 mm | Apedal | Single grain | Firm (dry) | No roots (0) | | | |
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**Other information: W**eathered rock at bottom of profile, metamorphic. Increase in clay content at 900mm onwards, with increasing rock.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP06 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** | | | **Ground Cover %** | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Rapidly drained | **Erosion Extent** Minor or present | |
| **Landform** Lower slope | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** Partially stabilised | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Other Information:** Higher density of vegetation than nearby site

**Landscape Photo (South)**

**Landscape Photo (West)**

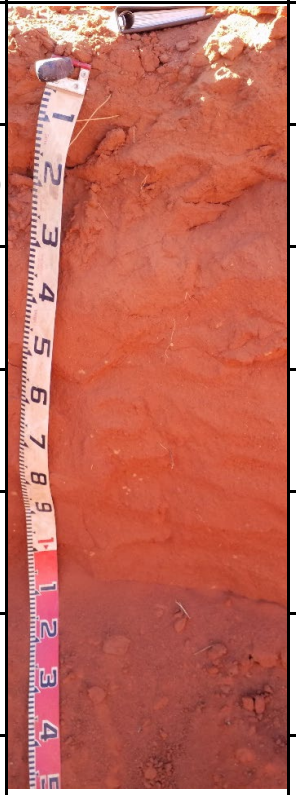
**Other Photo**

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.0 | 0.100 | 0-100 |
| B | 100-1100 | | N/A | Clayey Sand | 2.5YR 3/6 Dark red | 5% yellow | None evident | None evident | Apedal | Single grain | Firm (dry) | Few (1-10)<br>Very fine (<1 mm) | 5.5<br>6.0<br>6.0 | 0.038<br>0.016<br>0.015 | 200-300<br>500-600<br>800-900 |
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**Other information:** Deep sands. Arenic Rudosol.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP07 | **Observation** Soil pit | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | **Slope %** | | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Moderately well-drained | **Erosion Extent** Moderate | |
| **Landform** Lower slope | | | **Soil Surface Condition (dry)** Loose | | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Clear evidence of wind erosion of aelion sands.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-50 |  | Abrupt | Loamy Sand | 2.5YR 3/4 Dark reddish brown | None evident | None evident | None evident | Apedal | Single grain | Weak (dry) | Few (1-10) Fine (1-2 mm) | 6.3 | 0.010 | 0-100 |
| B | 50-750 | | Clear | Clayey Sand | 2.5YR 3/4 Dark reddish brown | None evident | None evident | None evident | Apedal | Single grain | Firm (dry) | Few (1-10) Fine (1-2 mm) | 6.3 | 0.060 | 200-300 |
| 2B21 | 750-1000 | | Clear | Loam | 2.5YR 3/4 Dark reddish brown | None evident | None evident | None evident | Apedal | Single grain | Very firm (dry) | No roots (0) | 6.1 | 0.070 | 800-900 |
| 2B22 | 1000-1150 | | N/A | Sandy Clay Loam | 2.5YR 3/4 Dark reddish brown | 2% white | <2 % Unidentified | None evident | Apedal | Massive | Strong (dry) | No roots (0) | 7.1 | 0.020 | 1000-1100 |
| | | | | | | | | | | | | | | | |
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**Other information:** Increasing clay content with depth, harder sandy clays past 700. No structure in profile.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP08 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Sparse (10-30%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | **Drainage (site)** Imperfectly drained | **Erosion Extent** None evident | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Firm | | **Land Use** Cleared | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Cleared area in core yard laydown, sand dune 100m away

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Polyhedral | Weak | Weak (dry) | Few (1-10) Fine (1-2 mm) | 7.0 | 0.028 | 0-100 |
| B1 | 100-450 | | Gradual | Clay Loam | 2.5YR 4/6 Red | None evident | None evident | None evident | Polyhedral | Weak | Firm (dry) | Few (1-10) Fine (1-2 mm) | 7.0 | 0.092 | 200-300 |
| B2 | 450-900 | | N/A | Light Medium Clay | 2.5YR 4/8 Red | White 10% | <2 % Unidentified | None evident | Subangular blocky | Weak | Strong (dry) | No roots (0) | 7.5 8.0 | 0.113 0.780 | 500-600 700-800 |
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**Other information:** black gravel 2% at 100mm onwards

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP09 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** | | | **Ground Cover %** | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Well-drained | **Erosion Extent** Moderate | |
| **Landform** Mid-slope | | | **Soil Surface Condition (dry)** Firm | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

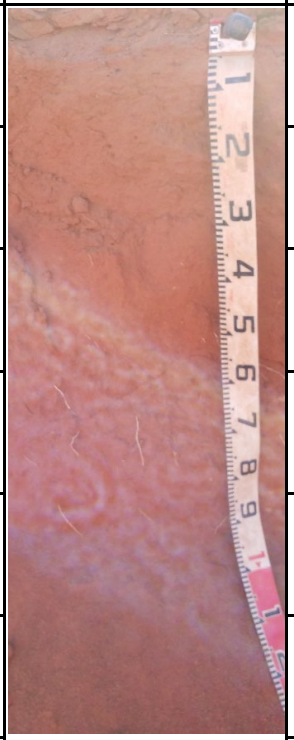
**Other Information:** 100m from sand dune.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-50 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Very weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.0 | 0.009 | 0-100 |
| B | 50-1000 | | N/A | Clayey Sand | 2.5YR 3/6 Dark red | 2% Yellow | None evident | None evident | Apedal | Single grain | Firm (dry) | Few (1-10)<br>Fine (1-2 mm) | 5.5<br>6.0<br>6.0 | 0.033<br>0.014<br>0.017 | 200-300<br>500-600<br>800-900 |
| | | | | | | | | | | | | | | | |
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**Other information:** Very consistent, roots down to 1000mm.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP10 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Imperfectly drained | **Erosion Extent** Minor or present | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Soft | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

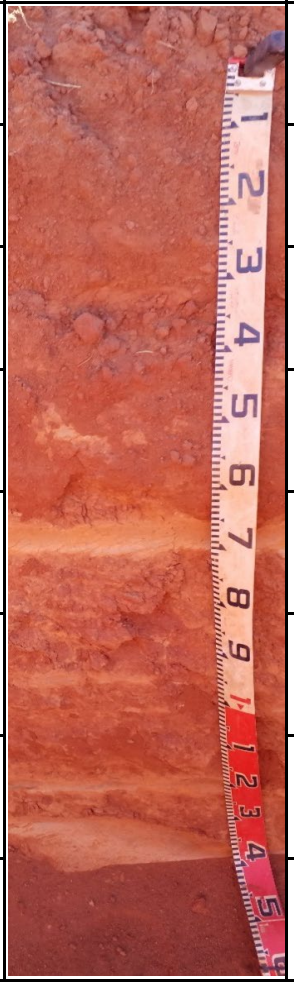
**Other Information:**

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Polyhedral | Weak | Very weak (dry) | Few (1-10) Fine (1-2 mm) | 6.0 | 0.014 | 0-100 |
| B21 | 100-450 | | Abrupt | Sandy Clay Loam | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Polyhedral | Weak | Firm (dry) | Few (1-10) Fine (1-2 mm) | 7.0 | 0.118 | 200-300 |
| B22 | 450-1400 | | N/A | Loam | 2.5YR 4/6 Red | None evident | None evident | None evident | Polyhedral | Weak | Very firm (dry) | No roots (0) | 7.5 8.0 | 0.071 0.053 | 500-600 900-1000 |
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**Other information:** Clay at 100 - 450, texture change at 450 onwards (slight decrease in clay despite shearing)

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP11 | **Observation** Soil pit | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Rapidly drained | **Erosion Extent** Moderate | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Loose | | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

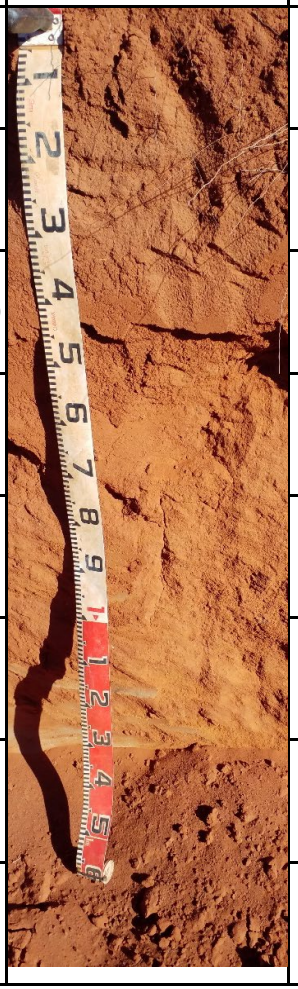
**Other Information:** Wind blown aelion sand

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Clayey Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Weak (dry) | Common (10-25)<br>Medium (2-5 mm) | 6.0 | 0.010 | 0-100 |
| B21 | 100-900 | | Abrupt | Clayey Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Firm (dry) | Few (1-10)<br>Very fine (<1 mm) | 5.8<br>5.8 | 0.040<br>0.060 | 200-300<br>500-600 |
| 2B | 900-1400 | | N/A | Sandy Loam | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Very firm (dry) | Not recorded | 6.6 | 0.020 | 1100-1200 |
| | | | | | | | | | | | | | | | |
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**Other information:** No coarse fragments, clay increases in bottom 1000-1400.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP12 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Rapidly drained | **Erosion Extent** Moderate | |
| **Landform** Mid-slope | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Wind blown sands

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-50 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Loose (dry) | Few (1-10) Fine (1-2 mm) | 6.5 | 0.017 | 0-100 |
| B | 50-1100 | | N/A | Loamy Sand | 2.5YR 3/6 Dark red | Yellow 5% | <2 % Carbonates | None evident | Apedal | Single grain | Very weak (dry) | Few (1-10) Medium (2-5 mm) | 5.5<br>6.0<br>6.0 | 0.010<br>0.020<br>0.011 | 200-300<br>500-600<br>800-900 |
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**Other information:** Consistent sands down the profile. 1mm thick layer of black at very top of profile (organic matter?).

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP13 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** | | | **Ground Cover %** | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Imperfectly drained | **Erosion Extent** Minor or present | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Wind blown sands.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Polyhedral | Weak | Weak (dry) | Common (10-25) Fine (1-2 mm) | 6.3 | 0.360 | 0-100 |
| B21 | 100-800 | | Abrupt | Sandy Clay Loam | 2.5YR 4/6 Red | None evident | None evident | 2-10 % 2-6 mm | Polyhedral | Weak | Firm (dry) | Few (1-10) Fine (1-2 mm) | 7.7 | 4.410 | 200-300 |
| B22 | 800-1000 | | Clear | Sandy Clay Loam | 2.5YR 4/6 Red | Yellow 5% | None evident | 20-50 % 2-6 mm | Apedal | Massive | Strong (dry) | No roots (0) | 7.9 | 3.050 | 500-600 |
| BC | 1000-1200 | | N/A | Light Clay | 2.5YR 4/6 Red | Yellow 5% | None evident | 50-90 % 2-6 mm | Apedal | Massive | Strong (dry) | No roots (0) | 7.4 | 7.670 | 800-900 |
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**Other information:** B22 could also be considered as a BC horizon, loader refusal at 1200mm. Hard compacted gravels and laterite.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP14 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Calcarosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | **Drainage (site)** Rapidly drained | **Erosion Extent** None evident | |
| **Landform** Lower slope | | | **Soil Surface Condition (dry)** Soft | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** within 400m of rocky hillside, wind blown sand surface.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-50 |  | Diffuse | Loamy Sand (coarse) | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Apedal | Single grain | Very weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.5 | 0.012 | 0-100 |
| B21 | 50-600 | | Gradual | Loamy Sand (coarse) | 2.5YR 4/6 Red | None evident | None evident | None evident | Apedal | Single grain | Very weak (dry) | Few (1-10)<br>Very fine (<1 mm) | 6.0<br>6.0 | 0.011<br>0.016 | 200-300<br>500-600 |
| B22 | 600-1000 | | N/A | Loamy Sand (coarse) | 2.5YR 4/6 Red | None evident | None evident | None evident | Apedal | Single grain | Weak (dry) | No roots (0) | 6.0 | 0.015 | 900-1000 |
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**Other information:** Consistent sands, perhaps silicious in nature.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP15 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Sparse (10-30%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** Wind | |
| **Vegetation (species)** | | | | | **Drainage (site)** Well-drained | **Erosion Extent** Moderate | |
| **Landform** Mid-slope | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** Active | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

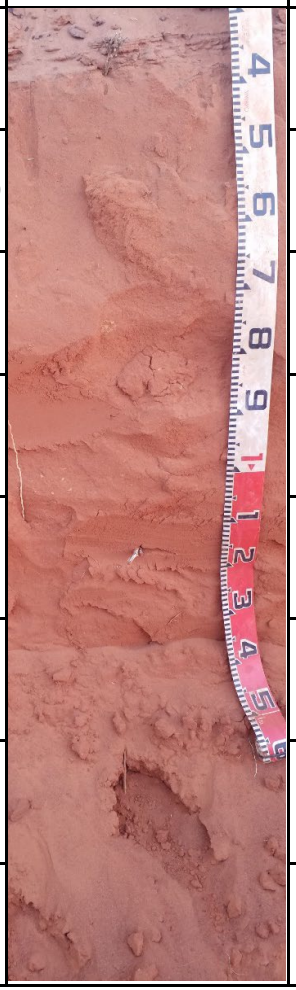
**Other Information:** Some plants covered in sand mounds, wind erosion prevalent

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 4/8 Red | None evident | None evident | None evident | Granular | Single grain | Very weak (dry) | Common (10-25)<br>Fine (1-2 mm) | 7.0 | 0.0 | 0-100 |
| B | 100-1400 | | N/A | Loamy Sand | 2.5YR 4/8 Red | None evident | None evident | None evident | Granular | Single grain | Very weak (dry) | Few (1-10)<br>Medium (2-5 mm) | 7.0<br>7.0<br>6.5 | 0.014<br>0.009<br>0.017 | 200-300<br>500-600<br>1100-1200 |
| | | | | | | | | | | | | | | | |
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**Other information:** Deep sandy profile, little variation.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP16 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | **Slope %** | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | **Drainage (site)** Well-drained | **Erosion Extent** None evident | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Soft | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Other Information:** Slight surface crust 1mm thick.

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-100 |  | Abrupt | Loamy Sand | 2.5YR 3/4 Dark reddish brown | None evident | None evident | None evident | Granular | Single grain | Weak (dry) | Common (10-25) Fine (1-2 mm) | 7.0 | 0.011 | 0-100 |
| B | 100-900 | | Clear | Loamy Sand | 2.5YR 3/6 Dark red | None evident | None evident | None evident | Granular | Single grain | Firm (dry) | Few (1-10) Fine (1-2 mm) | 7.5<br>7.5<br>7.5 | 0.014<br>0.032<br>0.021 | 200-300<br>500-600<br>800-900 |
| C | 900-1000 | | N/A | None evident | None evident | None evident | None evident | None evident | None evident | None evident | None evident | No roots (0) | | | |
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**Other information:** Looks to be wind deposited sands, hard rock at bottom of profile.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP17 | **Observation** Soil pit | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | **Slope %** | **Rock Outcrop** Slightly rocky | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | **Drainage (site)** Moderately well-drained | **Erosion Extent** None evident | |
| **Landform** Upper slope | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Other Information:** Rocks on surface 20-50mm 20-50%.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | 0-700 |  | Abrupt | Sandy Loam | 2.5YR 3/6 Dark red | 5% White and green sheared clay | 2-10 %<br>Clayey | 10-20mm 80% | Subangular blocky | Weak | Firm (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.5<br>6.5<br>6.5 | 0.019<br>0.017<br>0.014 | 0-100 200-300 500-600 |
| C | 700-1000 | | N/A | None evident | None evident | None evident | 2-10 %<br>Clayey | 50-90 %<br>60-200 mm | Apedal | Single grain | None evident | No roots (0) | | | |
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**Other information:** Portions of clay present at 400mm, profile increases in clay content slightly at depth, variable s iuzed coarse fragments throughout, c horizon is weathered and white,

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP18 | **Observation** Soil pit | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Calcarosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Slope %** | | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Moderately well-drained | **Erosion Extent** None evident | |
| **Landform** Lower slope | | | **Soil Surface Condition (dry)** Firm | | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Gravel on surface 2-10mm and up to 50mm, 40%. Surface is firmer than previous sites.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | ec | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-400 |  | Diffuse | Clayey Sand | 2.5YR 3/6 Dark red | None evident | None evident | 20-50 %<br>2-6 mm | Angular blocky | Moderate | Weak (dry) | Common (10-25)<br>Medium (2-5 mm) | 6.0<br>5.9 | 0.040<br>0.010 | 0-100<br>200-300 |
| B21 | 400-1100 | | Abrupt | Clayey Sand | 2.5YR 4/8 Red | None evident | None evident | 50-90 %<br>2-6 mm | Granular | Single grain | Very weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.3 | 0.010 | 600-700 |
| B22 | 1100-1200 | | N/A | Light Clay | 2.5YR 4/3 Reddish brown | None evident | None evident | 20-50 %<br>2-6 mm | Polyhedral | Weak | Firm (dry) | No roots (0) | 6.8 | 0.010 | 1100-1200 |
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**Other information:** Sandy at the top, gravel increases significantly at 500mm, clay at 1100. Structure of clay is likely weak or single grain (poor structure).

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP19 | **Observation** Soil pit | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Sparse (10-30%) | **Aspect** | | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Isolated Plants (<0.2%) | **Slope %** | | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Rapidly drained | **Erosion Extent** None evident | |
| **Landform** Flat | | | **Soil Surface Condition (dry)** Loose | | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Detailed + Sampled for Lab

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Loose sands qnd nothing else

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-50 |  | Abrupt | Loamy Sand (fine) | 2.5YR 3/4 Dark reddish brown | None evident | None evident | 2-10 %<br>2-6 mm | Granular | Single grain | Loose (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.5 | 0.012 | 0-100 |
| B21 | 50-800 | | Gradual | Loamy Sand (fine) | 2.5YR 3/6 Dark red | None evident | None evident | 2-10 %<br>2-6 mm | Granular | Single grain | Very weak (dry) | Few (1-10)<br>Fine (1-2 mm) | 6.5<br>6.5 | 0.008<br>0.012 | 200-300<br>500-600 |
| B22 | 800-1300 | | N/A | Loamy Sand (fine) | 2.5YR 3/6 Dark red | None evident | None evident | <2 %<br>2-6 mm | Granular | Single grain | Weak (dry) | No roots (0) | 6.0 | 0.012 | 900-1000 |
| | | | | | | | | | | | | | | | |
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**Other information:** Single grain sand. A few thin black layers at the top of the proifle approximately 1mm thick, then into consistent sands.

# Soil Profile Description

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|---|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP20 | **Observation** Manual auger | | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Mid-dense (30-70%) | **Aspect** | | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Rudosol |
| **Secondary Vegetation Form** Woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Slope %** | | **Rock Outcrop** No rock outcrop | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | | **Drainage (site)** Well-drained | **Erosion Extent** None evident | |
| **Landform** Lower slope | | | **Soil Surface Condition (dry)** Loose | | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Check

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

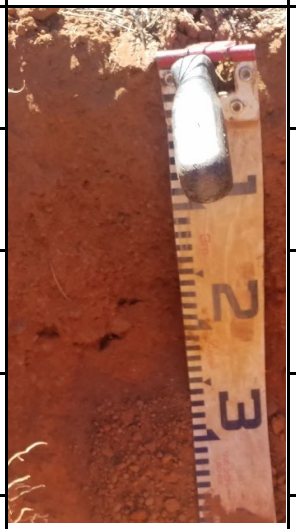
**Other Information:** Good shrub cover, scattered rocks on surface, leaf litter 20%

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B | 0-300 |  | N/A | Loamy Sand | 2.5YR 3/4 Dark reddish brown | None evident | None evident | 20-50 %<br>2-6 mm | Polyhedral | Weak | Firm (dry) | Common (10-25)<br>Fine (1-2 mm) | 6.5 | 0.015 | 0-100 |
| | | | | | | | | | | | | | | | |
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**Other information:** Consistent horizon.

# Soil Profile Description

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project** Haverion | **Date** | **Scribe** I. Kelder | **Location** TP21 | **Observation** Manual auger | **Easting/ Latitude** | **Zone** | **ASC Mapped** Tenosol |
| **Dominant Vegetation Form** Non-woody | | | **Ground Cover %** Very sparse (0.2-10%) | **Aspect** | **Northing/ Longitude** | **Scale** | **ASC Ground Truth** Kandosol |
| **Secondary Vegetation Form** | | | **Ground Cover %** | **Slope %** | **Rock Outcrop** Very slightly rocky | **Erosion Type** None evident | |
| **Vegetation (species)** | | | | | **Drainage (site)** Well-drained | **Erosion Extent** None evident | |
| **Landform** Mid-slope | | | **Soil Surface Condition (dry)** Loose | | **Land Use** Grazing | **Erosion State** None evident | |

**Landscape Photo (North)**

**Landscape Photo (East)**

**Soil Surface Condition Photo**

**Site Type**

Check

**Microrelief** N/A

**Type**

**Vertical (m)**

**Horizontal (m)**

**Sampled**

**Landscape Photo (South)**

**Landscape Photo (West)**

**Other Photo**

**Other Information:** Very sandy, some rock 10-20mm at 5%.

**Dominant Vegetation Photo 1**

**Dominant Vegetation Photo 2**

**Other Vegetation Photo**

# Soil Profile Description

| Horizon | Depth (mm) | Profile Photo | Boundary | Texture | Moist Colour | Mottle (colour, abundance) | Segregations (abundance, nature) | Coarse fragments (abundance, size) | Structure (type) | Structure (grade) | Consistence (soil water status) | Roots (abundance, size) | pH | EC (dS/m) | Depth of Sample for Lab (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 0-80 |  | Clear | Sandy Loam (fine) | 2.5YR 4/4 Reddish brown | None evident | None evident | 2-10mm 2% | Polyhedral | Weak | Firm (dry) | Common (10-25) Fine (1-2 mm) | 8.0 | 0.530 | 0-100 |
| B | 80-200 | | N/A | Clayey Sand (fine) | 2.5YR 3/6 Dark red | None evident | None evident | 2-10mm 2% | Apedal | Single grain | Very firm (dry) | Few (1-10) Fine (1-2 mm) | 8.0 | 0.165 | 100-200 |
| | | | | | | | | | | | | | | | |
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**Other information:** Tentative b, may be an A12 horizon. Top 2mm of profile loose sand into some structured sands.

# APPENDIX B – LABORATORY RESULTS

| Analyses | | Unit | TP02 0-100 | TP02 200-300 | TP02 500-600 | TP02 900-1000 | TP07 0-100 | TP07 200-300 | TP07 800-900 | TP07 1100-1200 |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | | pH units | 6.14 | 5.50 | 5.69 | 6.31 | 6.28 | 6.07 | 7.13 | 7.14 |
| Electrical Conductivity | | dS/m | 0.02 | 0.03 | 0.02 | 0.04 | 0.01 | 0.06 | 0.07 | 0.02 |
| Chloride | | mg/kg | 4.5 | 17.0 | 10.7 | 243.0 | 21.6 | 17.2 | 46.5 | 277.0 |
| Total Nitrogen | | mg/kg | <50 | - | - | - | <50 | - | - | - |
| Total Phosphorus | | mg/kg | 59.7 | - | - | - | 39.7 | - | - | - |
| Organic Carbon | | % | 0.12 | - | - | - | 0.08 | - | - | - |
| Plant Available Nutrients | Phosphorus - Colwell | mg/kg | 16.3 | - | - | - | 16.7 | - | - | - |
| | Potassium - Colwell | mg/kg | 113 | - | - | - | 98.1 | - | - | - |
| | Sulphur - KCl | mg/kg | 3.6 | - | - | - | 5.8 | - | - | - |
| | Copper – DTPA | mg/kg | <0.2 | - | - | - | <0.2 | - | - | - |
| | Iron – DTPA | mg/kg | 3.6 | - | - | - | 2.9 | - | - | - |
| | Manganese – DTPA | mg/kg | 6.5 | - | - | - | 7.0 | - | - | - |
| | Zinc – DTPA | mg/kg | <0.2 | - | - | - | <0.2 | - | - | - |
| Exchangeable Cations | Calcium | meq/100g | 0.62 | 0.62 | 0.82 | 1.95 | 0.83 | 2.36 | 1.45 | 1.66 |
| | Magnesium | meq/100g | 0.55 | 0.64 | 0.89 | 2.18 | 0.64 | 1.16 | 2.21 | 2.95 |
| | Potassium | meq/100g | 0.21 | 0.19 | 0.24 | 0.29 | 0.19 | 0.30 | 0.48 | 0.50 |
| | Sodium | meq/100g | 0.19 | 0.15 | 0.25 | 0.40 | 0.19 | 0.22 | 0.38 | 0.27 |
| | Aluminium | meq/100g | 0.08 | 0.12 | 0.03 | 0.01 | 0.06 | 0.02 | 0.04 | 0.01 |
| Effective Cation Exchange Capacity | | meq/100g | 1.6 | 1.7 | 2.2 | 4.8 | 1.9 | 4.1 | 4.6 | 5.4 |
| Exchangeable Sodium Percentage | | % | 4.9 | 8.6 | 11.1 | 8.4 | 9.8 | 5.4 | 8.2 | 5.0 |
| Particle Size Distribution of Fine Fraction | Coarse Sand 0.2-2.0mm | % | 50.3 | 48.0 | 44.6 | 44.1 | 45.9 | 47.3 | 46.7 | 57.9 |
| | Fine Sand 0.02-0.2mm | % | 43.6 | 42.5 | 44.2 | 44.4 | 46.0 | 34.5 | 32.8 | 36.1 |
| | Silt 0.002-0.02mm | % | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| | Clay <0.002mm | % | 5.0 | 8.4 | 10.1 | 0.0 | 7.0 | 17.2 | 19.5 | 4.9 |
| Dispersion Potential | | Class | 6 | 6 | 5 | 5 | 6 | 6 | 6 | 6 |

| Analyses | | Unit | TP11 0-100 | TP11 200-300 | TP11 500-600 | TP11 1100-1200 | TP13 0-100 | TP13 200-300 | TP13 500-600 | TP13 800-900 |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | | pH units | 5.95 | 5.80 | 5.77 | 6.61 | 6.29 | 7.71 | 7.92 | 7.41 |
| Electrical Conductivity | | dS/m | 0.01 | 0.04 | 0.06 | 0.02 | 0.36 | 4.41 | 3.05 | 7.67 |
| Chloride | | mg/kg | 3.6 | 45 | 28 | 5.9 | 533 | 5241 | 3513 | 7370 |
| Total Nitrogen | | mg/kg | <50 | - | - | - | <50 | - | - | - |
| Total Phosphorus | | mg/kg | 41 | - | - | - | 45 | - | - | - |
| Organic Carbon | | % | 0.13 | - | - | - | 0.18 | - | - | - |
| Plant Available Nutrients | Phosphorus - Colwell | mg/kg | 24.1 | - | - | - | 8.4 | - | - | - |
| | Potassium - Colwell | mg/kg | 103 | - | - | - | 123 | - | - | - |
| | Sulphur - KCl | mg/kg | 3.5 | - | - | - | 54.6 | - | - | - |
| | Copper – DTPA | mg/kg | <0.2 | - | - | - | <0.2 | - | - | - |
| | Iron – DTPA | mg/kg | 2.8 | - | - | - | 1.2 | - | - | - |
| | Manganese – DTPA | mg/kg | 5.3 | - | - | - | 2.6 | - | - | - |
| | Zinc – DTPA | mg/kg | <0.2 | - | - | - | <0.2 | - | - | - |
| Exchangeable Cations | Calcium | meq/100g | 0.68 | 0.83 | 1.03 | 1.48 | 1.27 | 1.24 | 0.95 | 27.74 |
| | Magnesium | meq/100g | 0.42 | 0.63 | 0.84 | 1.07 | 0.71 | 5.00 | 4.27 | 8.28 |
| | Potassium | meq/100g | 0.16 | 0.22 | 0.28 | 0.25 | 0.24 | 1.78 | 1.39 | 2.34 |
| | Sodium | meq/100g | 0.08 | 0.09 | 0.10 | 0.20 | 1.00 | 23.40 | 17.20 | 26.87 |
| | Aluminium | meq/100g | 0.04 | 0.05 | 0.03 | 0.01 | 0.02 | 0.03 | 0.01 | 0.01 |
| Effective Cation Exchange Capacity | | meq/100g | 1.4 | 1.8 | 2.3 | 3.0 | 3.2 | 31.4 | 23.8 | 65.2 |
| Exchangeable Sodium Percentage | | % | 5.7 | 5.0 | 4.4 | 6.5 | 42.2 | 29.5 | 29.1 | 57.5 |
| Particle Size Distribution of Fine Fraction | Coarse Sand 0.2-2.0mm | % | 57.9 | 59.3 | 51.8 | 49.2 | 51.3 | 47.0 | 46.9 | 55.9 |
| | Fine Sand 0.02-0.2mm | % | 36.1 | 31.1 | 36.6 | 35.6 | 40.8 | 30.3 | 30.5 | 23.0 |
| | Silt 0.002-0.02mm | % | 1.1 | 1.1 | 0.3 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| | Clay <0.002mm | % | 4.9 | 8.6 | 11.3 | 14.1 | 6.8 | 21.6 | 21.5 | 20.0 |
| Dispersion Potential | | Class | 5 | 5 | 6 | 6 | 5 | 6 | 6 | 6 |

| Analyses | | Unit | TP18 0-100 | TP18 200-300 | TP18 600-700 | TP18 1100-1200 |
|---|---|---|---|---|---|---|
| pH | | pH units | 5.98 | 5.94 | 6.32 | 6.75 |
| Electrical Conductivity | | dS/m | 0.04 | 0.01 | 0.01 | 0.01 |
| Chloride | | mg/kg | 16.9 | 6.4 | 4.8 | 4.4 |
| Total Nitrogen | | mg/kg | <50 | - | - | - |
| Total Phosphorus | | mg/kg | 85.6 | - | - | - |
| Organic Carbon | | % | 0.10 | - | - | - |
| Plant Available Nutrients | Phosphorus - Colwell | mg/kg | 20 | - | - | - |
| | Potassium - Colwell | mg/kg | 123 | - | - | - |
| | Sulphur - KCl | mg/kg | 7.1 | - | - | - |
| | Copper – DTPA | mg/kg | <0.2 | - | - | - |
| | Iron – DTPA | mg/kg | 1.91 | - | - | - |
| | Manganese – DTPA | mg/kg | 9.73 | - | - | - |
| | Zinc – DTPA | mg/kg | <0.2 | - | - | - |
| Exchangeable Cations | Calcium | meq/100g | 0.98 | 0.80 | 0.87 | 1.62 |
| | Magnesium | meq/100g | 0.70 | 0.65 | 0.75 | 1.05 |
| | Potassium | meq/100g | 0.21 | 0.24 | 0.23 | 0.24 |
| | Sodium | meq/100g | 0.38 | 0.15 | 0.13 | 0.13 |
| | Aluminium | meq/100g | 0.04 | 0.09 | 0.03 | 0.02 |
| Effective Cation Exchange Capacity | | meq/100g | 2.3 | 1.9 | 2.0 | 3.1 |
| Exchangeable Sodium Percentage | | % | 16.5 | 7.9 | 6.7 | 4.1 |
| Particle Size Distribution of Fine Fraction | Coarse Sand 0.2-2.0mm | % | 44.7 | 43.2 | 41.9 | 38.0 |
| | Fine Sand 0.02-0.2mm | % | 42.0 | 43.5 | 40.7 | 39.6 |
| | Silt 0.002-0.02mm | % | 0.1 | 0.1 | 1.1 | 1.1 |
| | Clay <0.002mm | % | 13.2 | 13.2 | 16.1 | 21.3 |
| Dispersion Potential | | Class | 5 | 6 | 6 | 5 |

# ADDENDUM

**TOOWOOMBA**
PO Box 57 HARLAXTON QLD 4350
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9 September 2022

2246.22b (Rev 1)

Attn: Louise Whitley

**Addendum: Revised Soil Characterisation – Havieron Proposed Haul Road Route**

## 1. Introduction

Newcrest Mining Limited (Newcrest) are preparing environmental assessments as part of a due-diligence exploration program for the Havieron Project (Havieron). Havieron is a farm-in joint venture agreement between Newcrest and Greatland Gold Limited, located 45km east of the Telfer Mine.

As part of this process, Landloch were engaged to deliver a soil characterisation report for the proposed Havieron project area. The final revision of this report was delivered in 2020[1]. Since completion of the report, a new haul road route has been proposed by Newcrest, located along the existing access track to Havieron. This haul road falls outside of the area previously surveyed[1].

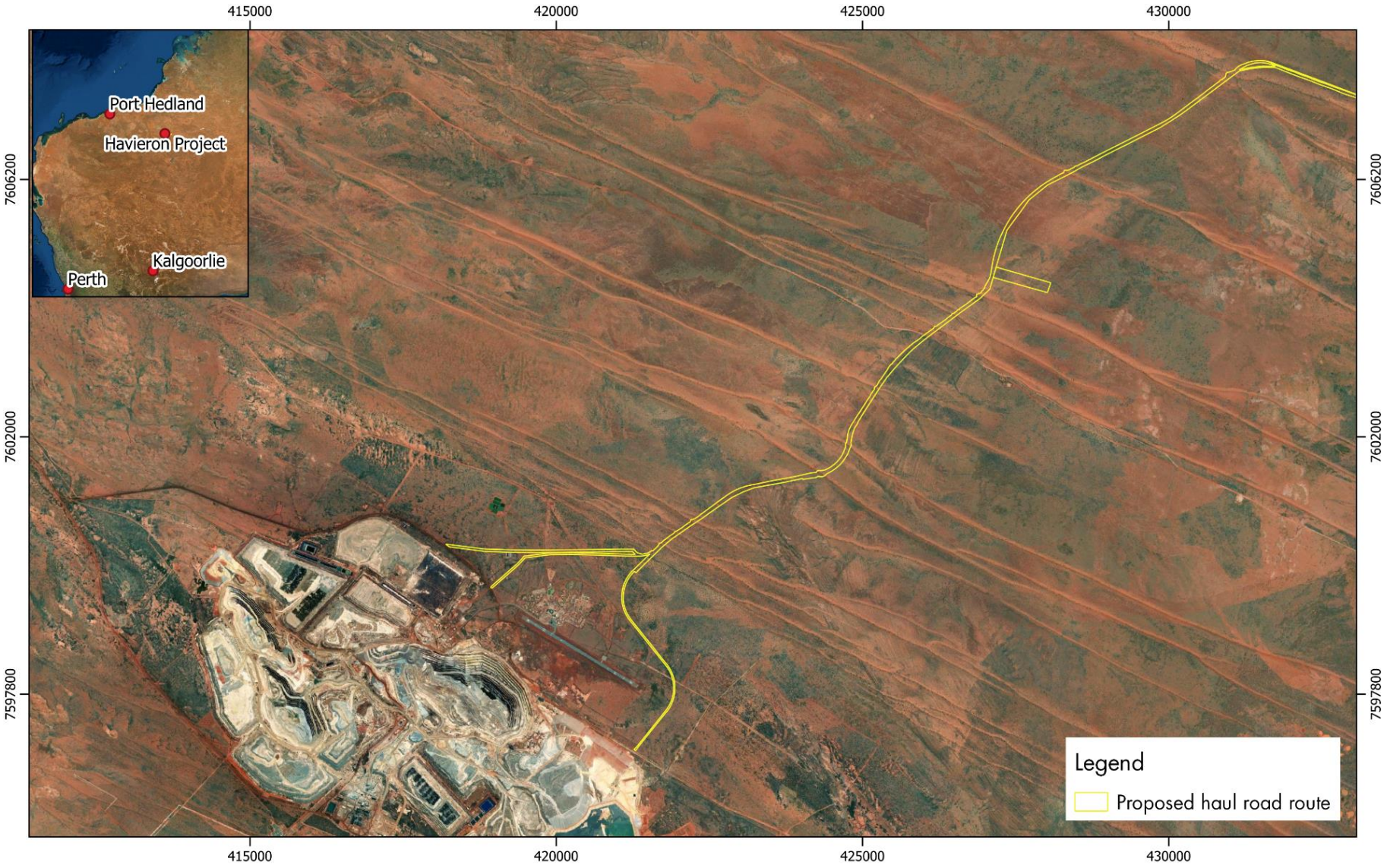
Newcrest has requested that Landloch expand the existing soil characterisation to include the proposed haul road route. This addendum to the Havieron Soil Characterisation Report[1] seeks to characterise the soils of the proposed haul road route.

### 1.1 Proposed haul road route

The proposed haul road route runs south-west from Havieron to Telfer for ~13km, before splitting into three route alternatives near Telfer (Figure 1). Alternative one runs directly west for ~3.5km and terminates near the Tailings Storage Facility at Telfer. Alternative two runs west and then south-west, terminating north of Telfer village. Alternative three runs south for ~4km, terminating near Telfer airport.

The main route including all three route alternatives are included in this assessment.

[1] Landloch (2020) *Newcrest Havieron Soil Characterisation Report*, Revision 3, Report prepared for Newcrest Mining Limited.




Coordinate System:
GDA 2020 MGA Zone 51
Projection: Transverse Mercator
Imagery: ESRI satellite
Scale:1:60,000

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Revised Soil Characterisation

**Figure 1:** Proposed haul road route

## 2. Data review

### 2.1 Soil characterisation survey

The soil characterisation survey[2] was used as the basis for mapping and characterisation of the soils along the proposed haul road route. The original survey[2] included an initial haul road route which ran north-west from Havieron before turning west to meet the main access track to Telfer. Only the start of the proposed haul road route is included in the existing mapping, with the remainder of the road located outside of the original survey area. It is likely (though not certain) that some of the soils along the proposed haul road route will have similar characteristics to those encountered in the previous survey.

Included in the survey was the definition of soil mapping units (SMUs) that group soils by their management requirements. Where possible, the soils of the proposed haul road route were classified in line with the SMUs defined previously[2]. A summary of the names and characteristics of the SMUs are outlined below:

- Deep Sands are wind-blown aeolian sands associated with sand dunes present throughout the landscape. These soils are dominated by fine sands with no appreciable silt or clay and no pedological development.
- Gradational Loams are characterised by a thin layer of wind-blown aeolian sands that grade rapidly to sandy loam, with a gradual increase in clay content from clay loam to light clay at depth. The influence of wind-blown aeolian sands is less apparent in these soils. Included in this unit are a:
    - Non-saline and non-sodic sub-unit (not saline or sodic); and
    - Saline and sodic sub-unit (highly saline and sodic).
- Gradational Sands are similar to the Deep Sands, except for a change in texture from sand to loam in the deeper B horizon. These soils are characterised by a buried horizon at depth that represents the original soil profile that was covered in wind-blown aeolian sands.

**Table 1:** Soil mapping units of Havieron[2].

| SMU | SMU sub-unit | Soil description |
|---|---|---|
| Deep Sands | - | Wind-blow aeolian dune sands with no pedological development |
| Gradational Loams | Non-saline and non-sodic | Sandy loams with a gradual increase in clay content at depth but no increasing salinity and sodicity at depth |
| | Saline and sodic | Sandy loams with a gradual increase in clay content at depth and increasing salinity and sodicity at depth |
| Gradational Sands | - | Wind-blow aeolian dune sands overlying loams to light clays |

[2] Landloch (2020) *Newcrest Havieron Soil Characterisation Report*, Revision 3, Report prepared for Newcrest Mining Limited.

## 2.2 Landscape mapping

The Atlas of Australian Soils[3] includes broadscale landscape mapping of the arid interior of WA, including the proposed haul road route. It was produced at a scale of 1:2,000,000. This mapping describes land with a recurring pattern of topography, soils, and vegetation. Given its broadscale, the defined landscape units are comprised of a number of soil types.

The existing landscape mapping over the proposed haul road route is captured within one unit, Fa32. Landforms within Fa32 consist of low ranges and hills largely on metamorphics and granites, but with some inclusions of sandstone and conglomerates. There are extensive areas of bare rock interspersed in places with dunes that have been built up by wind and flanked by small plains. The main soils are shallow stony earthy loams on hillslopes, and other soils occurring on dunes. These soils correspond to an Australian Soil Classification of Tenosol. Tenosols are soils with generally only weak pedologic organisation.

Overall, the data from the landscape mapping is of limited value. Its broad mapping scale means that it cannot be used to usefully determine differences in soil types along the proposed haul road route.

## 2.3 Geotechnical investigation

A geotechnical investigation of the proposed haul road route was completed by WSP[4] in July 2022. Test pit logs provide an indication of the soil depth, texture, gravel content, hardness, and lithology. A summary of the geotechnical test pit data including Landloch re-interpretation is provided as an attachment to this addendum. Data sourced from the test pit logs can be used in lieu of soil profile descriptions, noting that the type and detail of data recorded differs from that recorded within test pit logs generated during a soil survey.

Included in the WSP investigation was the excavation and logging of 21 test pits along or near the proposed haul road route. However, there is a segment starting at Havieron that is ~7km in length where no test pits were excavated (Figure 2). As such, data is not available for this section.

Overall, the geotechnical data is the key dataset relied upon for the extension of the existing soil mapping, as it includes observations of soil properties.

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[3] Northcote K.H., Isbell R.F., Webb A.A., Murtha G.C., Churchward H.M. and Bettenay E. (1968) *Atlas of Australian Soils,* Explanatory data for Sheet 10, Central Australia, CSIRO: Melbourne University Press.

[4] WSP (2022) *Havieron Mine Haul Road and Industrial Areas, Geotechnical Investigation Report on the Telfer to Quartzite Ridge Section of the Haul Road,* Report prepared for Newcrest Mining Limited.

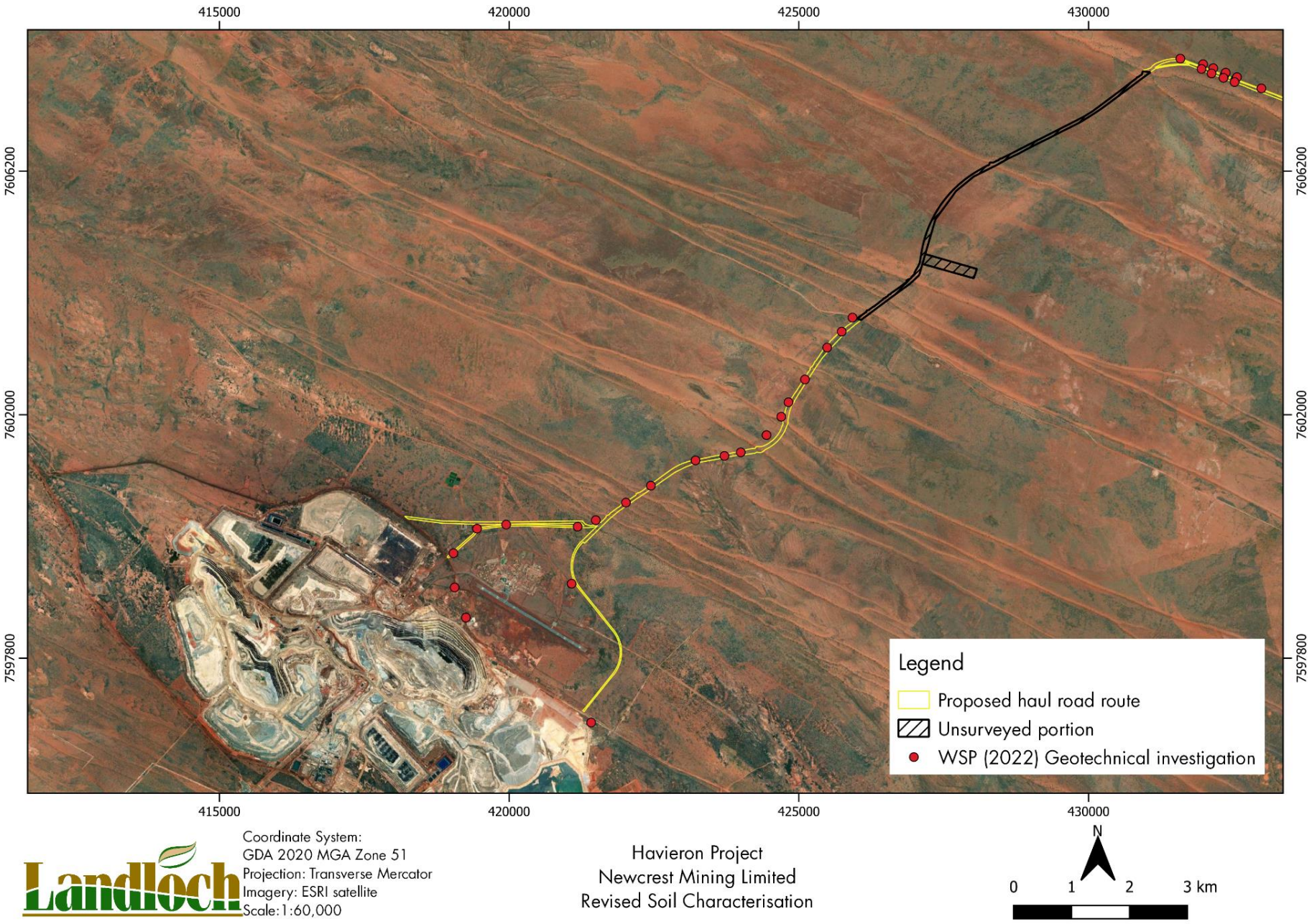



**Figure 2:** Geotechnical test pitting locations and unsurveyed portion of haul road

## 2.4 Vegetation mapping

A vegetation survey for the proposed haul road route was completed 2021, with shapefiles of the vegetation provided to Landloch by Newcrest. There are associations between vegetation type and soil type that can provide an indication of the soil profile and assist in soil mapping. As such, this data was used to assist in delineating soil types and boundaries.

The vegetation mapping was utilised by comparing the vegetation types within the proposed haul route to those present in the existing soils mapping. Where vegetation type and soil type matched, an association between the two was drawn. The review found that vegetation type and soil type are only broadly associated at Havieron and is generally only useful for determining the boundary between soil types.

# 3. Soil characterisation

The geotechnical data[5] was re-interpreted by Landloch to align with the data contained in Landloch's soil survey profile descriptions. This included depth, texture, coarse fragment type, density using Dynamic Cone Penetrometer (DCP), and material source. The data was used to assess similarities between the previously sampled soils[6] and those encountered by WSP along the proposed haul road route. Landloch's interpretation of the available data can be found at the end of this document. Note that the data is restricted to physical soil characteristics only. No data on soil chemical characteristics were available, and as such interpretation of the soils along the proposed haul road route is based on a limited set of physical characteristics only.

Based on the assessment outlined above, all three SMUs defined in the exsting survey were determined to be present along the proposed haul road route. In addition to the three SMUs from the original soil survey, two new soil associations were encountered along the proposed haul road route.

With reference to the three existing SMUs, the relationship between the data from the test pits and the SMUs are summarised below:

- Deep Sands – Test pits where aeolian sands were encountered at the surface of the profile to a depth of >1m were considered to fit within the Deep Sands SMU.
- Gradational Sands – Test pits where aeolian sands are present at the surface of the profile (~0.0-0.5m), and that overlie loamy soils were considered to fit the Gradational Sands SMU.
- Gradational Loams – Test pits where colluvium and lateritic soils are present throughout the soil profile or gravelly soils were considered to fit the Gradational Loams SMU. Note that in the Landloch 2020 report, Gradational Loams were split into non-saline non-sodic and saline sodic sub-units. As no chemical data was available for the test pits, we were unable to group the soils into these sub-units.

[5] WSP (2022) *Havieron Mine Haul Road and Industrial Areas, Geotechnical Investigation Report on the Telfer to Quartzite Ridge Section of the Haul Road*, Report prepared for Newcrest Mining Limited.
[6] Landloch (2020) *Newcrest Havieron Soil Characterisation Report*, Revision 3, Report prepared for Newcrest Mining Limited.

The characteristics of the two new soil associations are summarised below:

- Gravelly Sands – Test pits where gravel dominates the soil profile, usually occurring with either sand or silt. These can be shallow in some locations where bedrock is located closer to the surface.
- Rocky Sands – Test pits where the bedrock is located near to the surface, and the overlying material is comprised of cobble sized materials.

This assessment of the soils along the proposed haul road route is based on the available data. Landloch cannot provide certainty that the Deep Sands, Gradational Sands, and Gradational Loams identified within the proposed route match the SMUs previously mapped[7]. Additionally, Landloch can make no quantitative assessment of the characteristics of the two new soil associations identified and as such, cannot provide management strategies or stripping depths for these soils.

## 4. Mapping

A soils map (Figure 3) of the proposed haul road route was generated based on the following:

- Previous mapping;
- GPS location and characteristics of the test pits;
- Vegetation mapping; and
- Aerial imagery freely available for the survey area.

The map is provided in four sections in order for the soil associations to be more easily viewed.

The soil map includes the three SMUs from the previous survey[7] assumed to be present over the proposed haul road route, and the two new soil associations encountered. The area mapped includes the three alternative routes near Telfer and extends to the last geotechnical test pit excavated near Havieron.

A section of road ~7km in length exists, starting near Havieron and ending at the first geotechnical test pit for which data was limited to vegetation mapping and aerial imagery (i.e., no test pit data). Landloch assessed both the aerial imagery and the vegetation mapping to attempt to draw associations between vegetation, soil colour, and soil type, but found that these associations too weak to draw a correlation. As there was significant uncertainty in this section, the area was left unmapped.

[7] Landloch (2020) *Newcrest Havieron Soil Characterisation Report*, Revision 3, Report prepared for Newcrest Mining Limited.

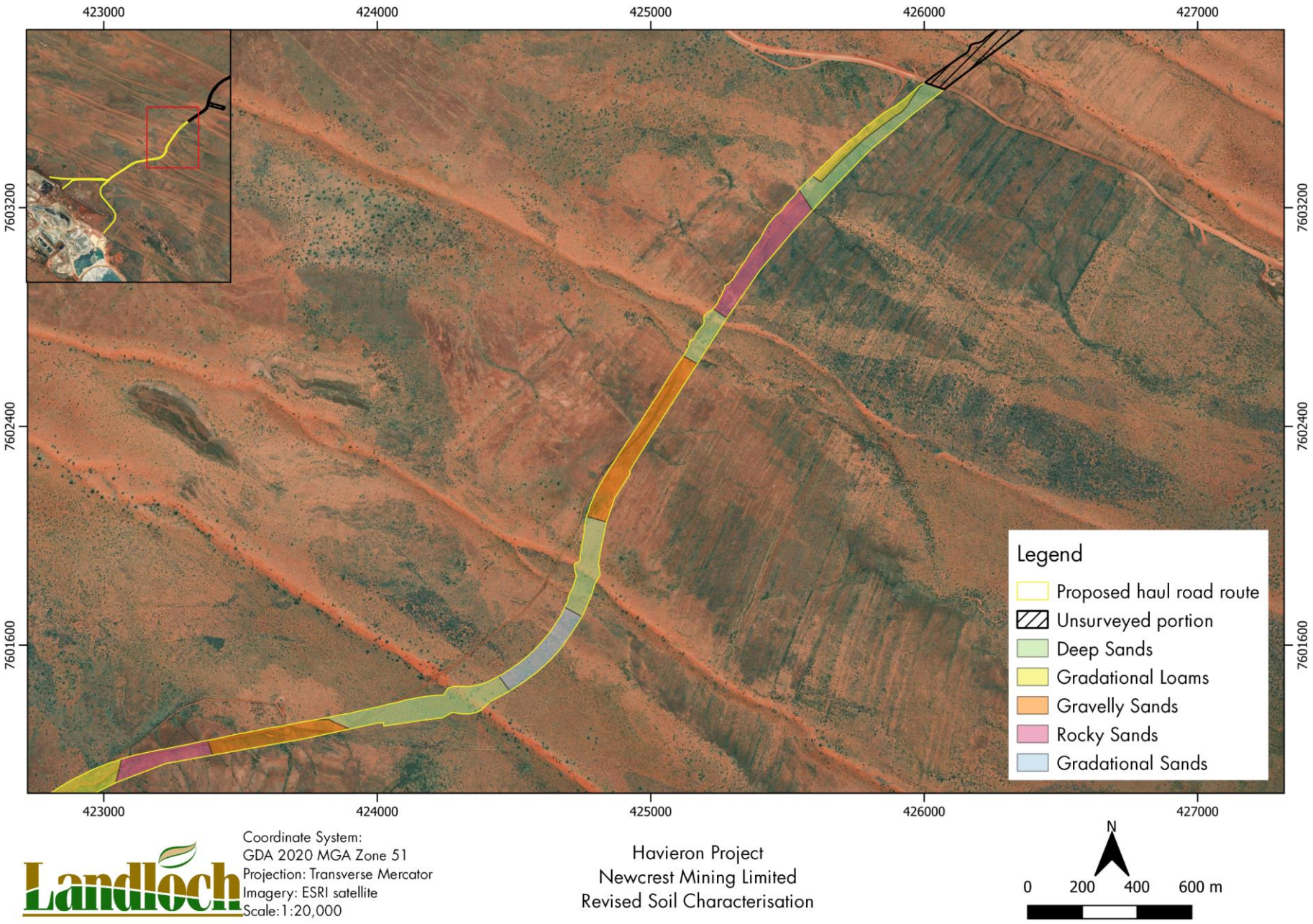



**Figure 3a:** Soil mapping units

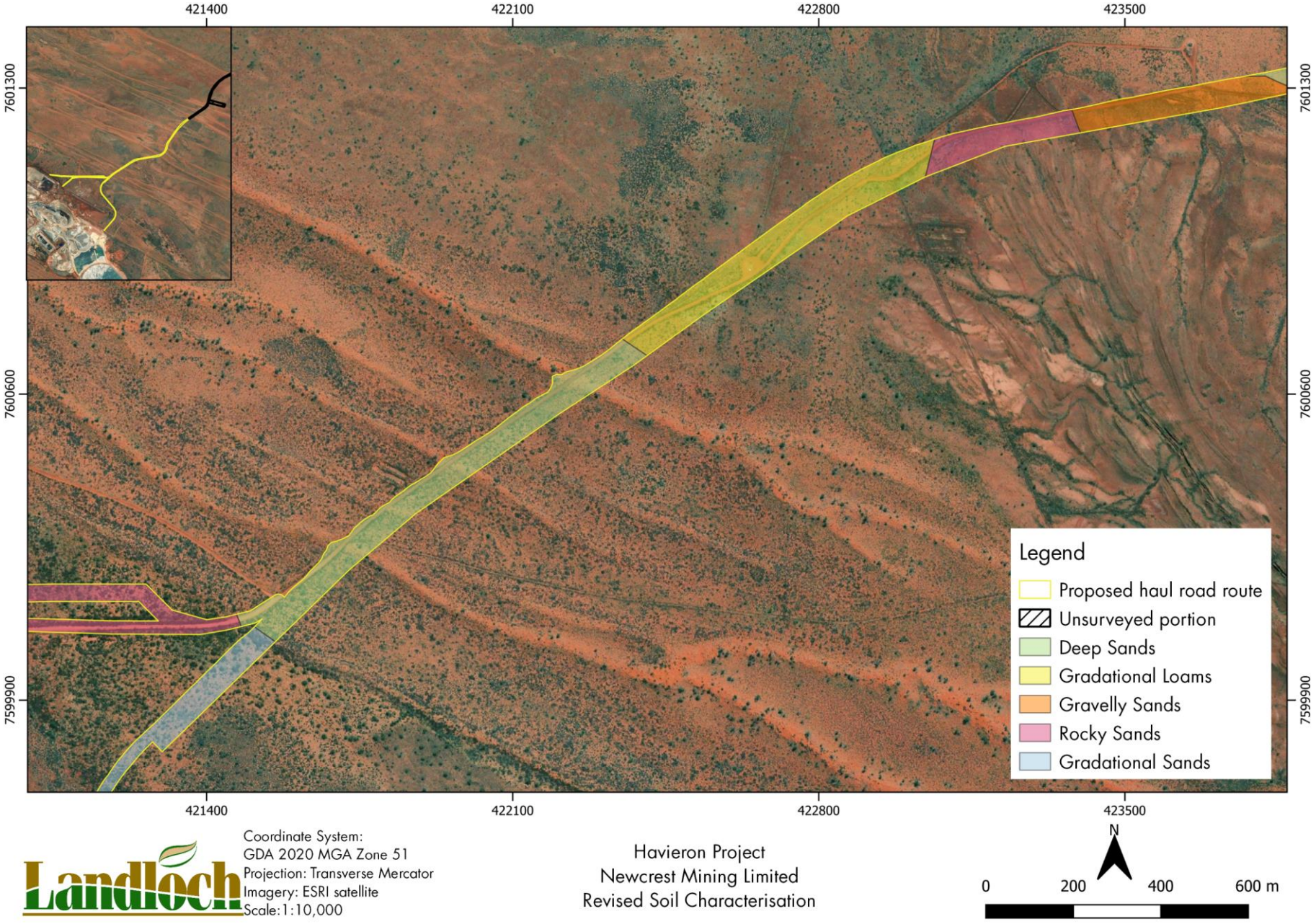



**Figure 3b:** Soil mapping units

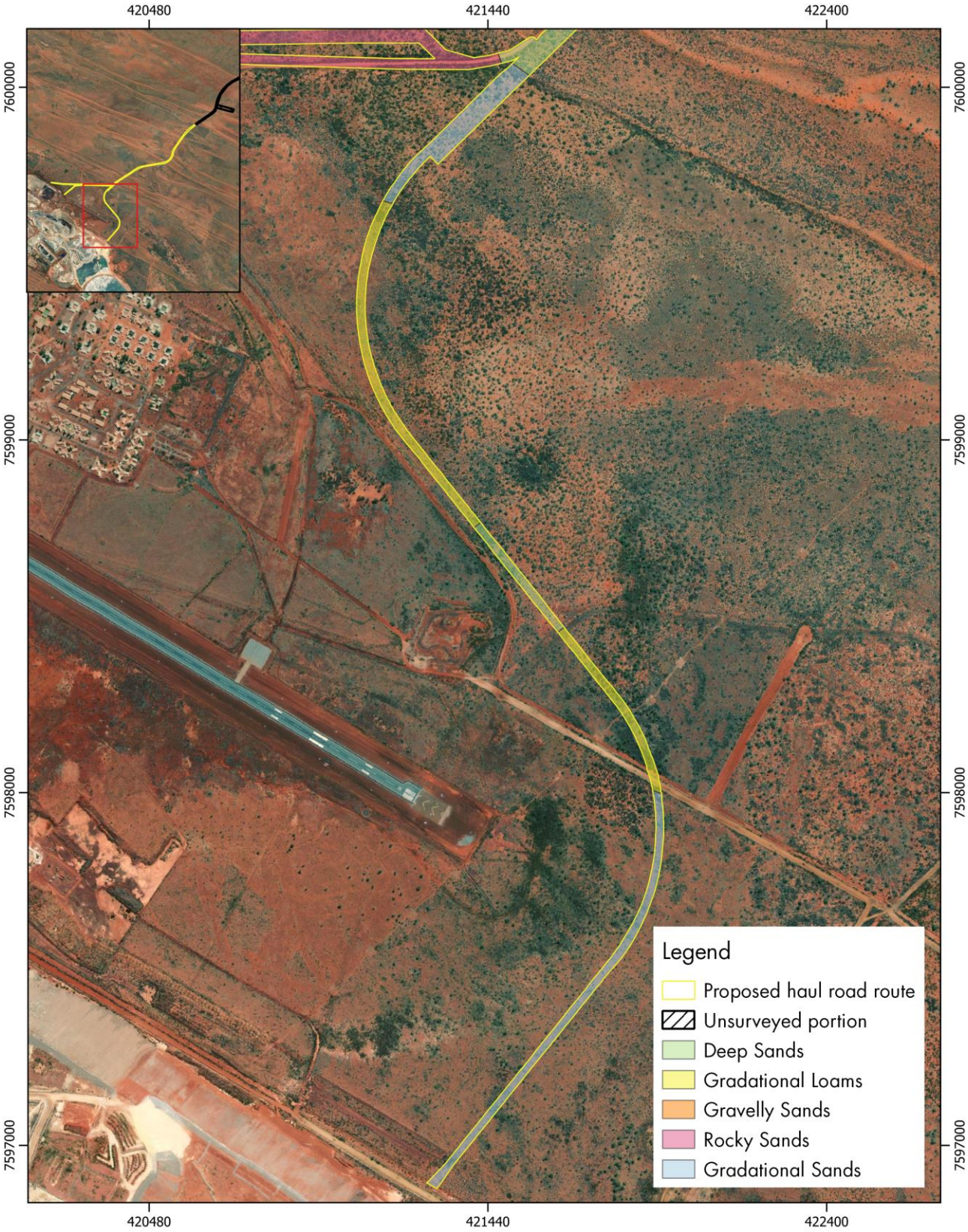
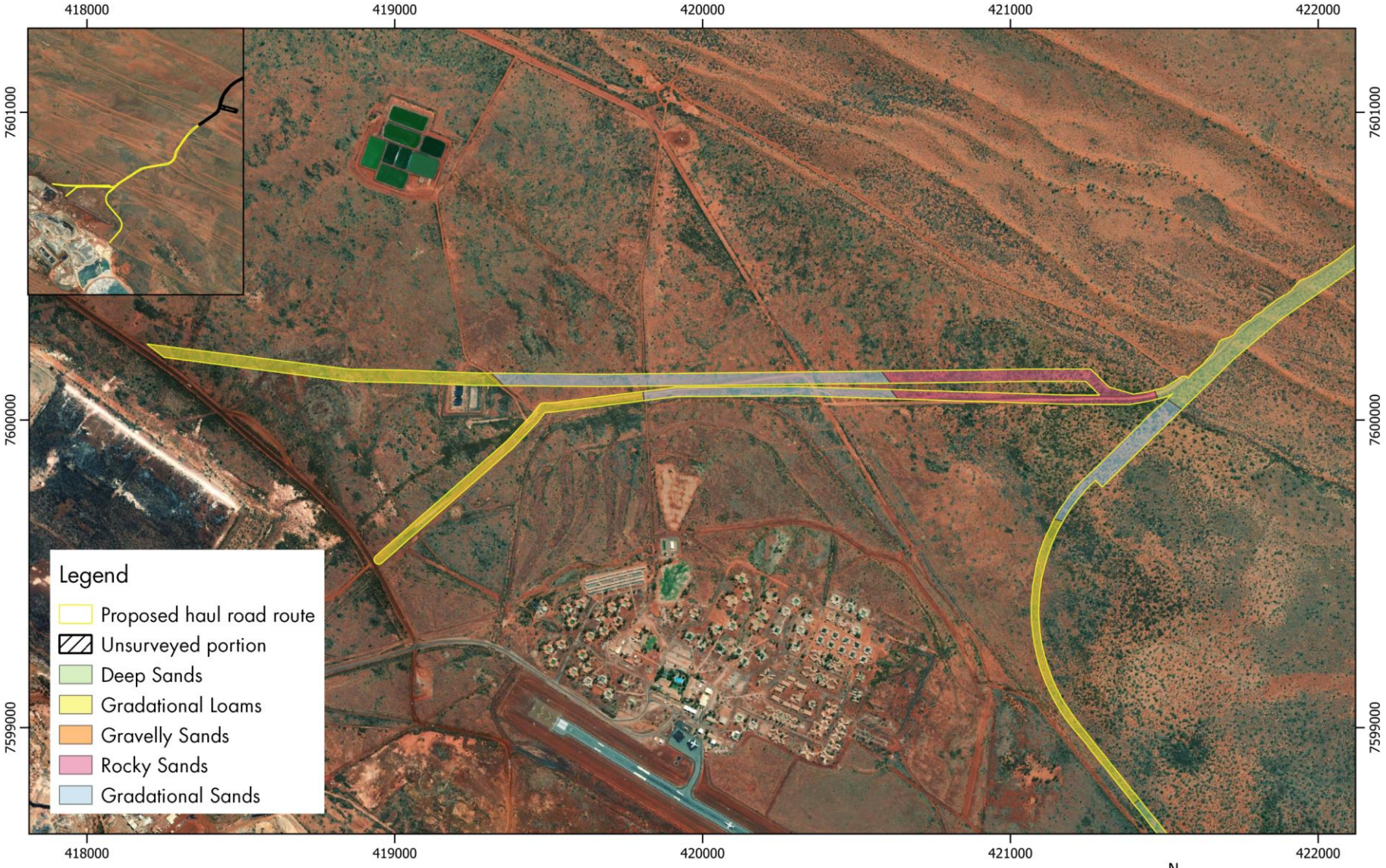



**Figure 3c:** Soil mapping units




Coordinate System:
GDA 2020 MGA Zone 51
Projection: Transverse Mercator
Imagery: ESRI satellite
Scale:1:15,000

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0 200 400 600 m

**Figure 3d:** Soil mapping units

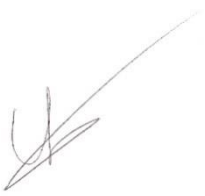
## 5. Conclusion

The results of the assessment found that all three previously mapped SMUs are likely to be present over the proposed haul road route. Two new soil associations that were not encountered in the previous soil survey are also likely to be present. Landloch have mapped the soils of the proposed haul road route but note there is a section of the road (~7km in length) that was unable to be mapped due to limitations in available data.

Landloch is unable to provide certainty around the soil types assumed to be present over the proposed haul road route, the characteristics and properties of these sorts, or the boundaries between each soil type. We note that no chemical data were available for review, and as such our interpretation is based only on physical data collected from the geotechnical test pits conducted by WSP.

It is recommended that a soil survey is conducted over the proposed haul road route to improve certainty regarding the properties and extent of the soils present, and to collect comprehensive physical and chemical characteristics and profile observations to determine how these soils should be managed during operations and at closure.

Regards

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Attachment: Geotechnical test pit descriptions.

**Disclaimer**

All care and diligence has been exercised in testing, interpreting data and the development of recommendations presented in this document. The monitoring and testing have been undertaken in a skilled, professional manner, according to accepted practices. Specific circumstances and research findings after the date of publication may influence the accuracy of the data and recommendations within this document.

The landscape is not uniform. Because of this non-uniformity, no monitoring, testing or sampling technique can produce completely precise results for any site. Any conclusions based on the monitoring and/or testing presented in this document can therefore only serve as a 'best' indication of the environmental condition of the site at the time of preparing this document. It should be noted that site conditions can change with time.

The information that comprises this document should only be used within the limitations stipulated herein. Landloch does not accept any risks and responsibilities for losses, damages, costs and other consequences resulting from using any information, material and recommendations in this document.

**Attachment:** Geotechnical data (WSP 2022) re-interpreted by Landloch.

| Pit number | Depth (m) | Texture | Coarse fragments | Density | Source |
|---|---|---|---|---|---|
| TP206 | 0.0-1.8 | Silty SAND | Gravels | DCP refusal 20cm | Aeolian soil |
| | 1.8-2.0 | Sandy Silty GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP207 | 0.0-1.0 | GRAVEL | Gravels | DCP refusal 10cm | - |
| | 1.0-2.2 | Silty Sandy GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP208 | 0.0-0.6 | SANDSTONE | Cobbles and gravels | DCP refusal 10cm | - |
| TP209 | 0.0-0.4 | Gravelly SAND | Cobbles and gravels | DCP refusal 40cm | Colluvium/ lateritic soil |
| | 0.4-1.6 | SANDSTONE | Gravels | | Wilki Fm Sandstone |
| TP210 | 0.0-1.3 | GRAVEL | Gravels | DCP refusal 30cm | Colluvium/ lateritic soil |
| TP211 | 0.0-1.2 | Silty SAND | Gravels | DCP refusal 40cm | Aeolian soil |
| | 1.2-2.1 | GRAVEL | None | | Colluvium/ lateritic soil |
| TP212 | 0.0-0.3 | Silty SAND | Trace gravels | DCP refusal 20cm | Aeolian soil |
| | 0.3-2.0 | GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP213 | 0.0-1.8 | Silty SAND | Trace gravels | DCP refusal 20cm | Aeolian soil |
| | 1.8-2.3 | Sandy Silty GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP214 | 0.0-1.5 | GRAVEL | Gravels | DCP refusal 30cm | - |
| | 1.5-2.2 | SANDSTONE | Gravels | | Wilki Fm Sandstone |
| TP215 | 0.0-0.5 | QUARTZITE and laterite | Cobbles and gravels | DCP refusal 10cm | - |
| TP216 | 0.0-1.2 | Silty Sandy GRAVEL | Gravels | DCP refusal 10cm | Colluvium/ lateritic soil |
| | 1.2-2.0 | Silty Sandy GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP217 | 0.0-2.0 | Silty SAND | Gravels | - | Colluvium/ lateritic soil |
| TP220 | 0.0-1.8 | Silty SAND | None | DCP refusal 20cm | Aeolian soil |
| | 1.8-2.1 | Sandy Silty GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP221 | 0.0-0.6 | FILL: Sandy GRAVEL | Gravels | - | Fill |
| | 0.6-1.4 | SAND | Gravels | | Aeolian soil |
| | 1.4-3.2 | Sandy GRAVEL | Cobbles and gravels | | Colluvium/ lateritic soil |
| TP222 | 0.0-0.1 | SANDSTONE | None | DCP refusal 10cm | Puntapunta Formation Dolarenite |

| Pit number | Depth (m) | Texture | Coarse fragments | Density | Source |
|---|---|---|---|---|---|
| TP223 | 0.0-0.7 | GRAVEL | Gravels | DCP refusal 40cm | - |
| | 0.7-1.2 | Sandy Gravelly SILT | Gravels | | Aeolian soil |
| TP224 | 0.0-0.6 | Silty SAND | Gravels | DCP refusal 100cm | Aeolian soil |
| | 0.6-1.4 | Sandy Silty GRAVEL | Gravels | | Colluvium/ lateritic soil |
| | 1.4-1.9 | GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP225 | 0.0-0.6 | Silty Sandy GRAVEL | Gravels | DCP refusal 10cm | - |
| | 0.6-1.5 | SILTSTONE | Cobbles and boulders | | Puntapunta Formation Silstone |
| TP226 | 0.0-0.5 | Sandy GRAVEL | Gravels | - | Colluvium/ lateritic soil |
| | 0.5-1.2 | Gravelly SAND | Gravels | | Colluvium/ lateritic soil |
| | 1.2-2.1 | Sandy GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP227 | 0.0-0.5 | Gravelly Silty SAND | Gravels | - | Colluvium/ lateritic soil |
| | 0.5-1.6 | Sandy Silty GRAVEL | Gravels | | Colluvium/ lateritic soil |
| TP228 | 0.0-0.5 | GRAVEL | Gravels | - | Colluvium/ lateritic soil |
| | 0.5-1.5 | Silty Sandy GRAVEL | Gravels | | Colluvium/ lateritic soil |
| | 1.5-2.0 | Gravelly CLAY | Gravels | | Puntapunta Formation Silstone |