# Landforms Assessment

## Winu Project

### Rio Tinto Winu Pty Ltd.

Prepared by:

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Making Sustainability Happen

## Revision Record

| Revision | Date | Prepared By | Checked By | Authorised By |
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# Basis of Report

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Rio Tinto Winu Pty Ltd. (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

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# 1.0 Introduction

## 1.1 Background

Rio Tinto Winu Pty Ltd (Rio Tinto) plans to develop a new copper-gold mine, referred to as the Winu Project (the Project), approximately 300 km south of Broome and 320 km east of Port Hedland in the Paterson Province in the Pilbara Region of Western Australia. The Project includes development of an open cut below water table pit, waste rock dumps, ore processing facilities, mine dewatering infrastructure, water supply infrastructure, linear infrastructure and support facilities.

The Project is located in the Great Sandy Desert. An extensive system of linear sand dunes is present in the Great Sandy Desert, including in the Project area. These sand dunes are the dominant landform in and around the Project area.

## 1.2 Objective

The objective of this work was to assess the significance of the dunal landform within the Mine and Infrastructure Area against the EPA criteria for determining the significance of a landform (EPA 2018).

## 1.3 Landforms

A landform is a feature on the earth's surface that is part of the terrain such as hills, mesas and plains. The EPA (2018) defines landforms as:

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

The EPA (2018) defines dunes as "a mound or ridge of sedimentary particles, usually sand, formed by the action of either wind or water". Based on these definitions, this assessment has considered each dune as a landform, collectively forming a dune system or land system.

## 1.4 Legislative and Policy Framework

Legislative instruments exist at both Federal and State levels that directly or indirectly support the protection of landforms. The legislation most relevant to protection of landforms for this project is the *Environmental Protection Act 1986* (EP Act). Under this Act, 'environment' is defined as "living things, their physical, biological and social surroundings, and interactions between all of these". When a proposal is assessed under the EP Act, the Environmental Protection Authority (EPA) may consider a proposal's impact to landforms under its guidance framework for environmental factors based on a number of environmental factors and environmental objectives listed in the Statement of Environmental Principles, Factors and Objectives.

The EPA's objective for the Landforms factor is "to maintain the variety and integrity of significant physical landforms so that environmental values are protected". The significance of a landform can be assessed through consideration of the following characteristics:

- Variety
- Integrity
- Ecological importance
- Scientific importance
- Rarity

- Social importance.

A landform does not need to meet criteria under all characteristics listed above to be considered significant.

## 1.5 Assessment Guidelines and Standards

This report was prepared with reference to the following guidelines and standards:

- Environmental Protection Authority 2018, Environmental Factor Guideline – Landforms (EPA 2018)
- Environmental Protection Authority 2020, Statement of Environmental Principles, Factors and Objectives (EPA 2023)

# 2.0 Methods

## 2.1 Defining the Local Assessment Units

EPA (2018) recommends defining a Local Assessment Unit (LAU) to consider whether a landform is significant and to enable consideration of potential changes to the landform.

Landscape Assessment Units should be defined on a case-by-case basis and should be configured to include aspects of the environment such as geology or morphology and to enable consideration of the position of landforms within the broader landscape (EPA 2018).

To enable assessment of the dunal landform, three LAUs were defined to provide context at a local, regional and national scale (Figure 1):

- MDA: The Mine Development Area, total extent of 20,407 ha. Note the MDA has been defined only for the purposes of this assessment, based on a generalised area covering the proposed locations of key mining infrastructure.
- 20K Area: The MDA plus a 20 km buffer, total extent of 288,266 ha
- Simpson Desert: total extent of 90,000 ha

The extent and location of each of these LAUs was selected such that:

- The LAUs intersected a sufficient number of linear sand dunes to enable meaningful statistical analysis of landform characteristics without being so large as to result in computational issues
- The LAUs were of different sizes to enable comparison at different scale.

Four additional areas (comparison sites) were analysed in the Great Sandy Desert, outside the 20K Area to crosscheck the suitability of the 20K Area and to provide additional regional context (Figure 2). The size, shape and orientation of the four comparison sites is the same as the MDA. The areas were selected from aerial imagery by looking for visually similar landforms in the north, east, west and south of the MDA.

**Rio Tinto**

**Winu Landform Assessment**

**Landscape Assessment Units**

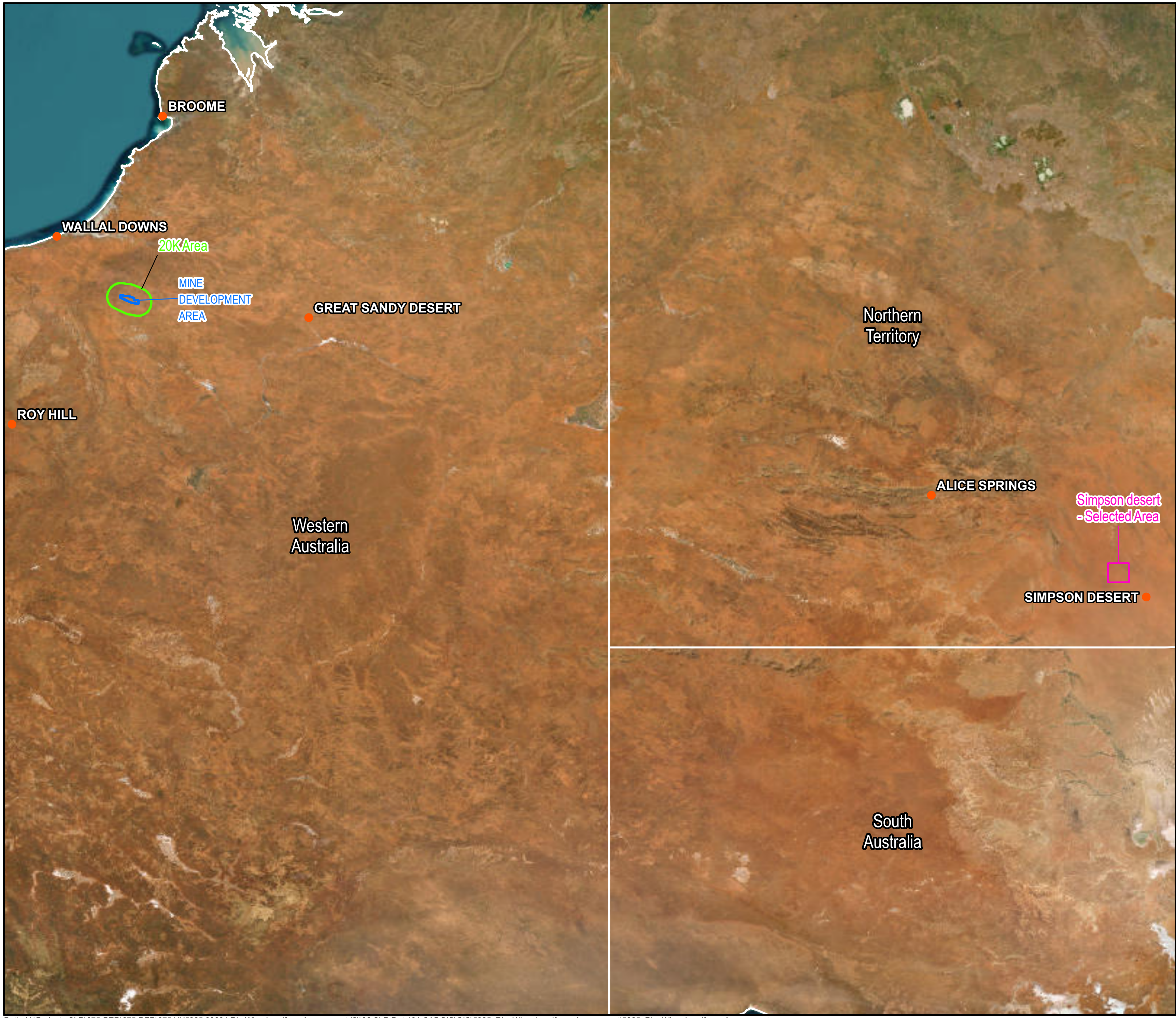
**FIGURE 1**

LEGEND

Mine Development Area

Simpson Desert Selected Area

20K Area

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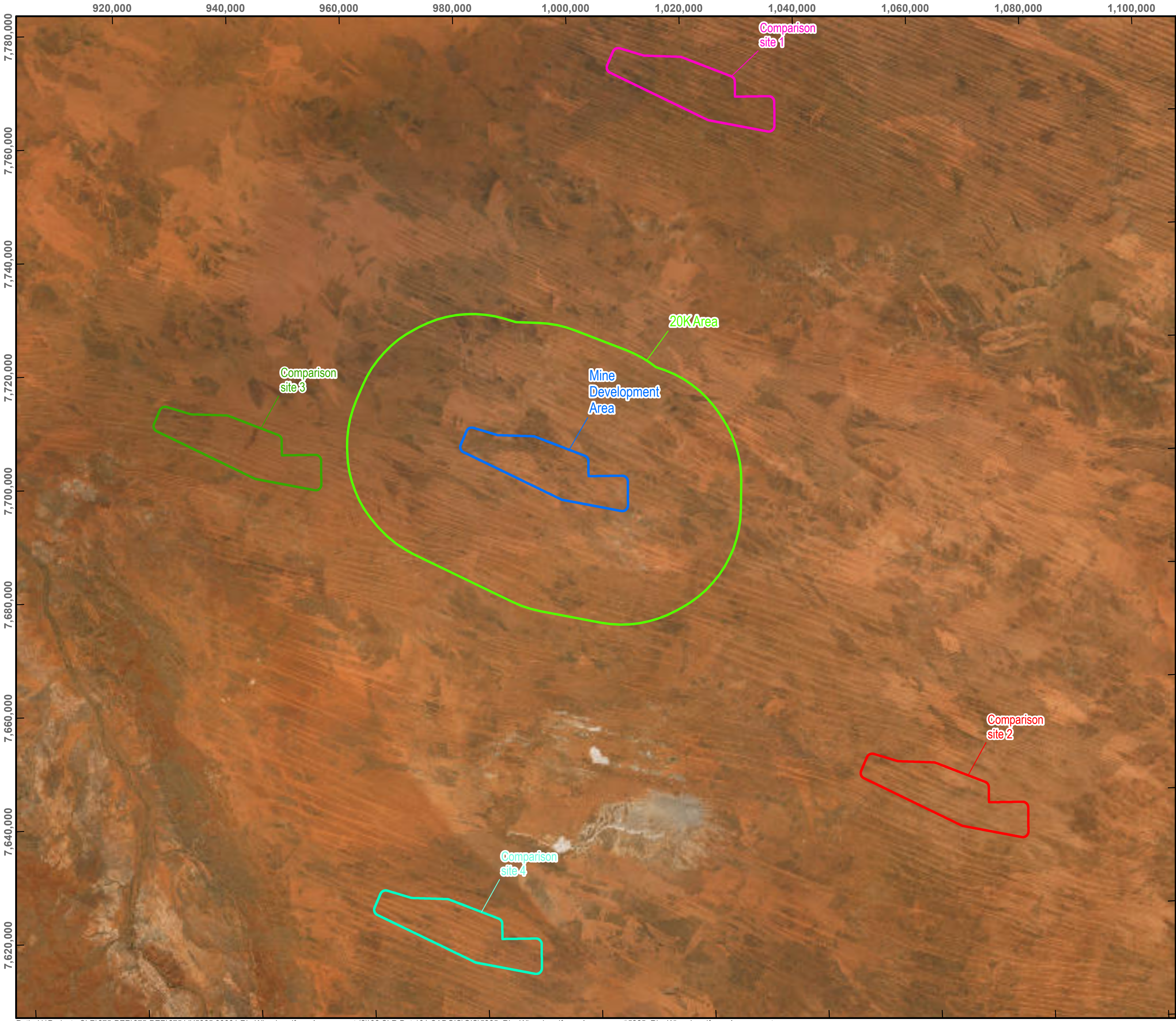


**Rio Tinto**

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**Comparison Sites**

**FIGURE 2**

LEGEND

- Comparison site 1
- Comparison site 2
- Comparison site 3
- Comparison site 4
- Mine Development Area
- 20K Area

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## 2.2 Data Collection

Spatial data were collected from the following sources:

- Sentinel Data (Subscription-Based): Acquired through a subscription to Sentinel satellite imagery
- SRTM Data from USGS: Elevation data from the United States Geological Survey's Shuttle Radar Topography Mission
- Esri Imagery: Imagery from Esri, provider of Geographic Information System (GIS) software
- Landgate Imagery: Integrated relevant imagery from Landgate, the Western Australian Land Information Authority.

## 2.3 Data Pre-processing

The data collected in Section 2.2 were pre-processed to ensure uniformity and suitability for analysis:

- Re-projection to Local Coordinate System: All data were re-projected to the local coordinate system MGA94-51 to ensure consistency in spatial reference
- Digital Elevation Model (DEM) Data Extraction: Elevation data were extracted for the areas of interest
- Vector Data Creation: Vector data were generated as per the specific needs and parametres outlined in the study.

## 2.4 Spatial Analysis

Spatial analysis techniques were used to examine characteristics of the dunal landform including morphology, presence of water, and vegetation health and coverage as detailed below. Outputs from the spatial analysis were graphed and represented cartographically.

### 2.4.1 Morphology

#### 2.4.1.1 Shape

To classify the shape of the landforms, the ‘geomorphons‘ methodology was applied to the DEM data for the areas of interest. This technique utilises an algorithm that analyses the distinctive signature of each terrain feature. The analysis comprised two key steps:

- Terrain Signature Creation: A systematically laid-out grid was imposed on the DEM. At each grid intersection the terrain within a pre-defined radius was scanned by the algorithm to calculate the variations in elevation between the central point and its closest neighbours. These variations were encoded into a unique numerical pattern known as the 'geomorphon' which captures the local topography around the central point.
- Terrain Decoding: A library containing 498 distinct geomorphons, each associated with a specific terrain shape category (peak, valley, ridge, etc.), was used as the reference for decoding the terrain's characteristics. Each geomorphon generated from the DEM analysis, was compared against this library to find the closest match (Jasiewicz & Stepinski 2013).

This two-stage approach provided an objective framework for classifying the terrain shape in the areas of interest.  The result of this analysis comprises ten main terrain shapes (Plate 1).

In order to examine whether differences in terrain shapes shown in the detailed analysis described above are present when a broader categorisation of terrain shapes is considered, the data for the ten terrain shapes shown in Plate 1 were aggregated to consider three broad terrain shapes:

- Slope (comprising Slope, Shoulder, and Spur classifications from the detailed assessment)
- Ridge (comprising Peak and Ridge from the detailed assessment)
- Low Slope/Flat (comprising Flat, Hollow, Footslope, Valley and Pit from the detailed assessment).

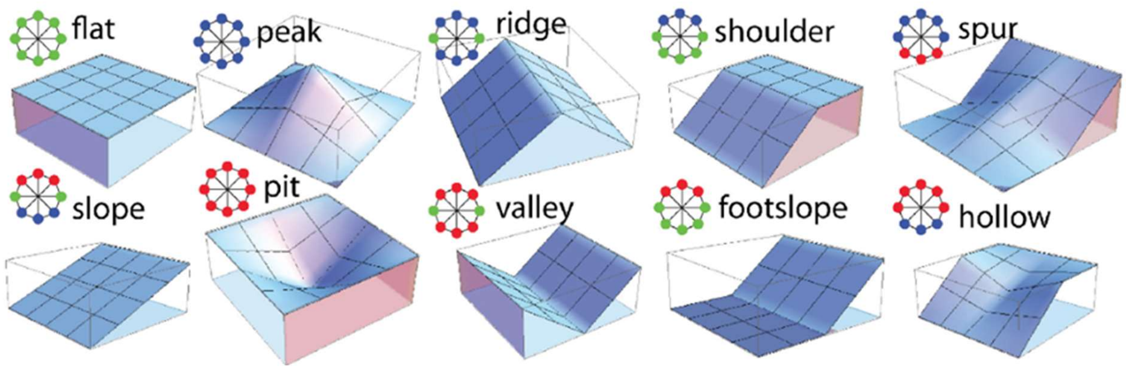



**Plate 1: Shape Types (Jasiewicz & Stepiski, 2013)**

#### 2.4.1.2 Slope

Slope was derived as a topographic parametre from a DEM. The slope parametre quantifies the rate of change in elevation on each cell or pixel of the model. It is a measure of terrain steepness, expressing the inclination of the land surface.  A DEM at 30 metre resolution was used for the slope analysis. The algorithm was used to analyse the surrounding cells to calculate the slope as a percentage of rise, with the range extending from 0 to essentially infinity. A flat surface is represented by 0 percent, a 45-degree surface by 100 percent, and as the surface becomes more vertical, the percentage rise becomes increasingly larger. The results were grouped into six ranges (class 1 to class 6) for the analysis of the areas of interest and comparison purposes, with no averaging applied to the results.

#### 2.4.1.3 Aspect

Aspect analysis identifies the direction the downhill slope faces. The results present the compass direction of the surfaces, measured clockwise from 0 (due north) to 360 (due north). Flat areas were excluded from the analysis of slope aspect. A DEM at 30 metre resolution was used for the aspect analysis. For the calculation, each cell within the DEM was examined in relation to its neighbouring cells to determine the direction of the slope at that location. The algorithm was used to find the elevation differentials between the central cell and the surrounding cells, employing a comparative approach to discern the downhill orientation.

#### 2.4.1.4 Dune Ridgelines over Time

Analysis of the dunes over time was undertaken by first utilising high-resolution imagery, Sentinel-2, to digitise the crestlines of the dunes. Sentinel-2 offered the most suitable spatial resolution for the areas analysed. Multispectral bands provided detailed observations and a panchromatic band further enhanced this capability. This process was completed for two points in time, June 2018 and July 2023. The five year separation period was selected to enable assessment of potential changes in the landforms. This period was selected as it allowed for potential short-term changes to be identified while still utilising imagery at a relatively high resolution. Long-term analysis of dunal changes over time is not currently possible as the maximum period for which high resolution imagery is available in this area is six years.

### 2.4.2 Indices

Vegetation was identified through the use of multispectral satellite imagery utilising the Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Moisture Index (NDMI). These indices serve as indicators for the health of vegetation and the presence of water.

The NDVI is a widely used remote sensing index that quantifies the presence and health of vegetation in an area. NDVI measures the difference between the reflectance of near-infrared radiation (NIR) and red light wavelengths from satellite imagery.

The NDWI is a spectral index designed primarily for the accurate mapping of water bodies. Calculated from satellite imagery, NDWI leverages the differences in reflectance between the NIR and green bands. Water bodies typically exhibit higher NDWI values, making NDWI a reliable indicator for their identification. NDWI is used in delineating water bodies, aiding in hydrological assessments, environmental monitoring, and land cover classification

The NDMI is a spectral index utilised to assess vegetation water content and monitor moisture levels in vegetation-covered areas. NDMI measures the difference in reflectance between NIR and short-wave infrared (SWIR) bands.

Satellite imagery was sourced from Sentinel Hub.

### 2.4.3 Ecology

Given the remoteness of the LAUs, ecological data are limited to broad-scale desktop information and data from ecological surveys conducted in specific proposed development areas. Several botanical surveys have been conducted across the MDA, these were consolidated by Western Botanical (2023). No detailed botanical data are available for the 20K Area. The closest comparable area within the Great Sandy Desert with detailed botanical data is a survey completed for British Petroleum's (BP's) Australian Renewable Energy Hub (AREH). Comparison of the BP AREH dataset with the Western Botanical Winu dataset to investigate similarities between mapped vegetation units was considered. However, due to the differing scales, survey effort and methodology for the two surveys and a large portion of the AREH data being located in a different biogeographic sub-region to the Winu data, the survey results are not directly comparable to those from the MDA.

A summary of Western Botanical's *Interim Consolidated Detailed Flora and Vegetation Assessment for the Winu Project* (2023) and Biota's Winu Terrestrial Fauna Interim Consolidation Report (2023) is provided to give the ecological context of the MDA and wider surrounds including consideration of whether the survey results indicate the dunes support endemic or highly restricted flora.

## 2.5 Assessment of Significance

Data from the spatial analysis were used to assess the significance of the dunal landforms in a local, regional and national context against the following EPA landform significance criteria (EPA 2018):

- Variety – The landform is a particularly good or important example of its type. The landform is not well represented over the local, regional or national scale or differs from other examples at these scales, either naturally or as a result of cumulative impacts from existing and reasonably foreseeable activities, developments and land uses.

- Integrity – The landform is intact, being largely complete or whole and in good condition.
- Ecological importance – The landform has a distinctive or exclusive role in maintaining ecological and physical processes; for example, by providing a unique microclimate, source of water flow, or shade. The landform supports endemic or highly restricted plants or animals.
- Scientific importance – The landform provides evidence of past ecological processes or is an important geomorphological or geological site. The landform is of recognised scientific interest as a reference site or an example of where important natural processes are operating.
- Rarity – The landform is rare or relatively rare, being one of the few of its type at a national, regional or local level

The EPA (2018) notes a landform does not need to meet criteria under all characteristics listed above to be considered significant.

Social importance of the dunal landform was not included in this assessment as this aspect will be considered separately by Rio Tinto as part of an assessment of Social Surroundings.

## 2.6 Limitations

The following limitations are associated with this landform assessment:

- The assessment has been completed at a desktop level utilising spatial data and available ecological data. Ecological surveys conducted in the area focus on species and habitat with limited information about ecological and physical process associated with the dunal landforms.
- Ecological data in the vicinity of the Winu area are limited to broad-scale desktop information and data from ecological surveys conducted in specific proposed development areas.
- The closest detailed ecological surveys to the Winu Project area are those conducted for the AREH. The location in a different biogeographic sub-region and differing scale, survey effort and methodology of the AREH surveys compared with the Winu ecological surveys restricted potential analysis of ecological data.
- Short range endemics (SREs) were not considered as part of this assessment.
- A DEM with a resolution of 30 metres was used for comparison of the areas of interest. While this resolution provides a good level of accuracy for landform assessments, it may not capture every nuance of the landforms. The inherent limitations of a 30-metre resolution should be considered in the interpretation of the results.
- The landform assessment relies on remote sensing data and geospatial algorithms for geospatial analysis. The inherent constraints of remote sensing and algorithmic approaches introduce a level of approximation that should be considered when interpreting the findings.

# 3.0 Results

Results of the spatial analysis described in Section 2.4 are presented in Sections 3.1 to 3.5 .

## 3.1 Interim Biogeographic Regionalisation of Australia (IBRA)

The Interim Biogeographic Regionalisation of Australia (IBRA) divides Australia into 89 bioregions based on major biological, geographical, and geological attributes. These bioregions are subdivided into 419 subregions as part of a refinement of the IBRA framework (DCCEEW, 2022). Both the MDA and 20K Area occur within the Great Sandy Desert (GSD) bioregion and the Mackay (GSD02) subregion (DCCEEW 2022).

The Great Sandy Desert bioregion is mainly a tree steppe in the north grading to shrub steppe in south. The climate is arid tropical with summer rain. The bioregion is dominated by Quaternary red longitudinal sand dune fields overlying Jurassic and Cretaceous sandstones of the Canning and Armadeus Basins. Vegetation comprises open hummock grassland of *Triodia pungens* and *T. schinzii* with scattered trees of Desert Walnut and Bloodwoods, and shrubs of *Acacia* spp, *Grevillea wickhamii* and *G. refracta*. *Casuarina decaisneana* (Desert Oak) occurs in the far east of the region.

The Mackay subregion is described as the tropical inland 'red-centre' desert and includes the 'Percival' and 'Auld' palaeoriver systems (McKenzie et al 2003). The climate is arid tropical with summer rainfall.

## 3.2 Land Systems

Land system mapping is based on regional patterns in topography, soils and vegetation. Land systems present in the MDA and 20K Area are summarised in Table 1. All land systems are distributed beyond the LAUs.

**Table 1: Land Systems within the MDA and 20K Area**

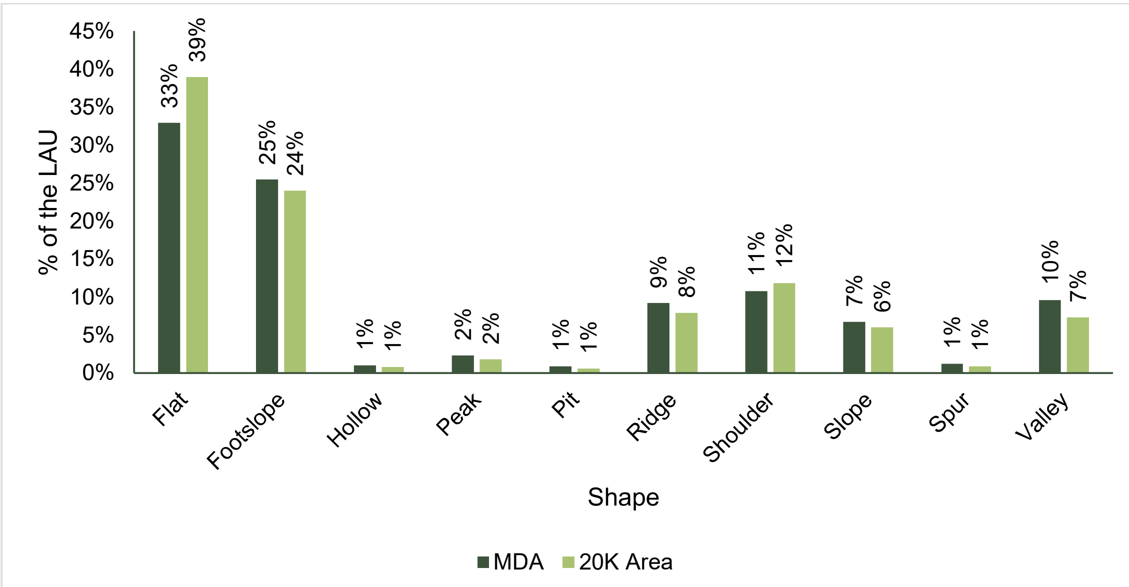
| System and Description | Total Extent | Extent within the MDA | Extent of the MDA within the System | Extent within the 20K Area | Extent of the 20K Area within the System |
|---|---|---|---|---|---|
| **AB40 Atlas System**<br>Gently undulating plain slightly more elevated than unit AB39, and dominated by longitudinal dunes, many exposures of ironstone gravels and some breakaways capped by ironstone (laterite) duricrust | 6,056,895 ha | 2,930 ha<br>14.36% | 0.05% | 136,208 ha<br>47.25% | 2.25% |
| **B30 Atlas System**<br>Dune fields--largely stable linear dune fields with swales opening locally into sand plains dune | 195,210 ha | 51 ha<br>0.25% | 0.03% | 8,765 ha<br>3.04% | 4.49% |

| System and Description | Total Extent | Extent within the MDA | Extent of the MDA within the System | Extent within the 20K Area | Extent of the 20K Area within the System |
|---|---|---|---|---|---|
| lineation is generally E.-W. but in the area west of 123 deg E. Longitude the trend is NW.-SE.; considerable areas of clay pans and salt pans | | | | | |
| **Buckshot**<br><br>Gravelly sandplains and occasional sand dunes supporting shrubby hard spinifex grasslands | 300,069 ha | - | - | 1,523 ha<br><br>0.53% | 0.51% |
| **Little Sandy**<br><br>Sandplains with linear and reticulate dunes supporting shrubby hard and soft spinifex grasslands | 2,102,527 ha | 17,426 ha<br><br>85.39% | 0.83% | 141,771 ha<br><br>49.18% | 6.74% |

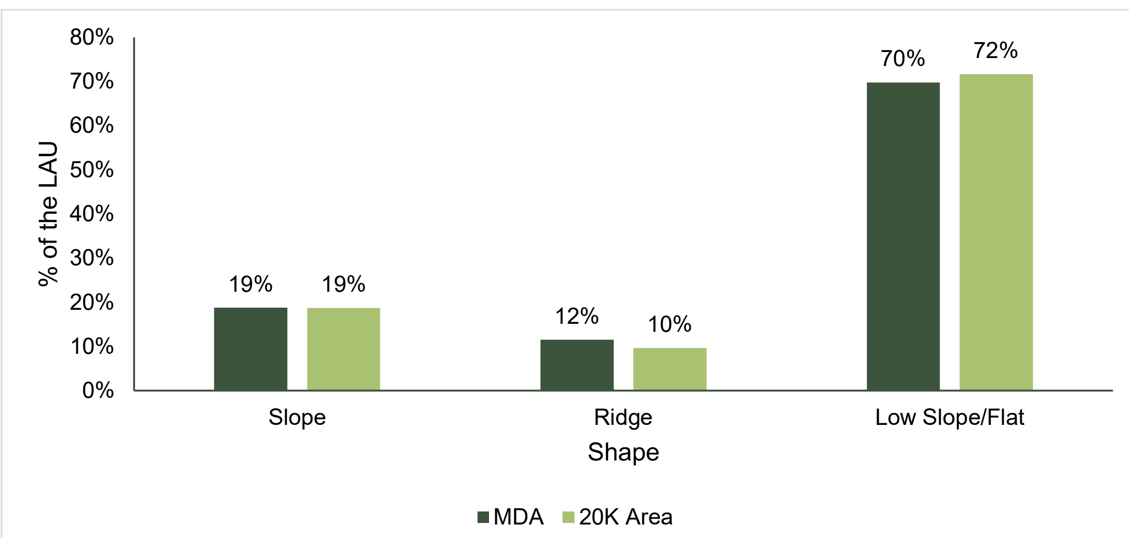
## 3.3 Morphology

### 3.3.1 Shape

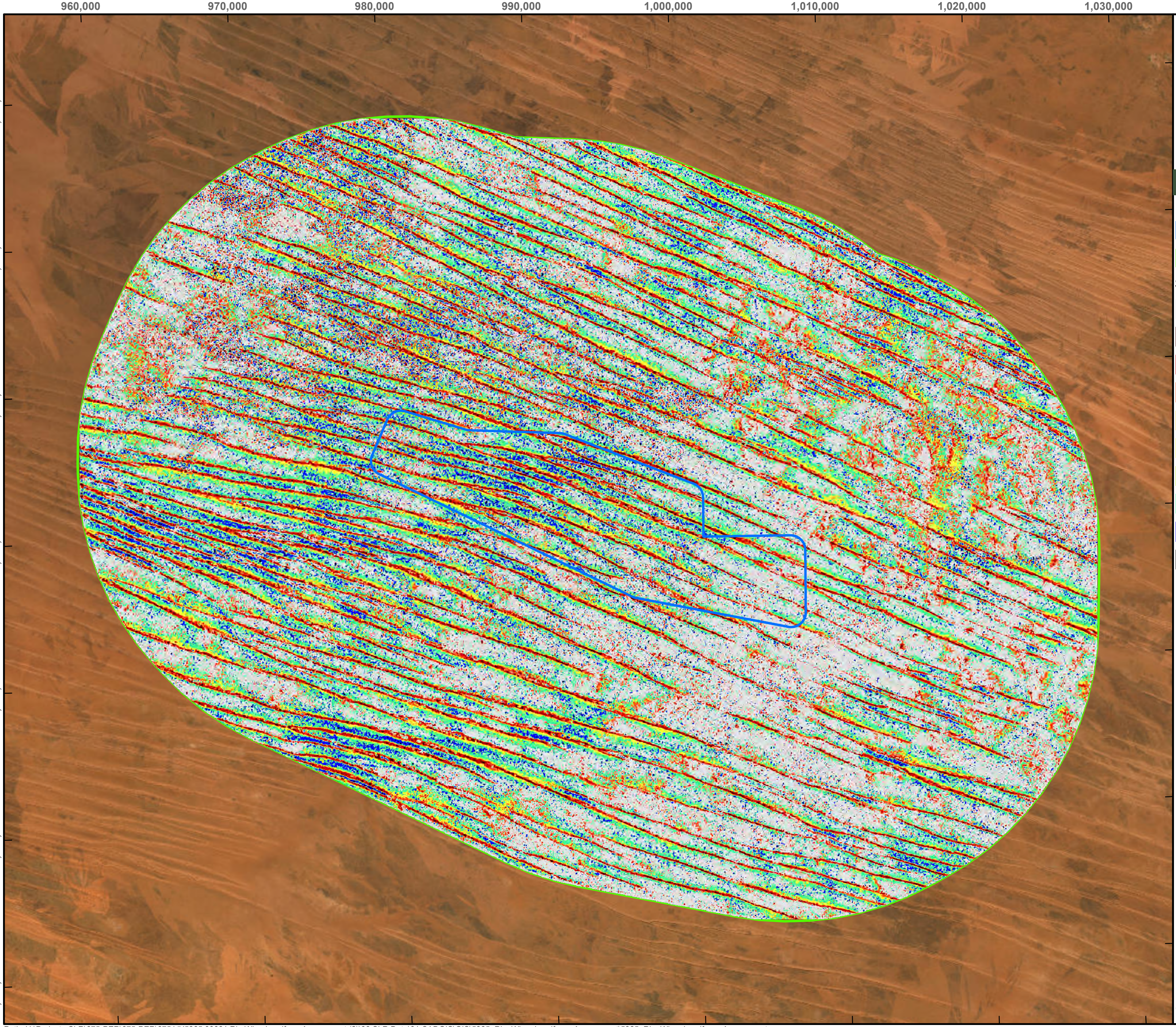
The landforms in the LAUs were classified spatially into different landform shapes using differences in elevation as described in Section 2.4.1.1. Figure 3 shows small variation of the detailed landform shapes between the two LAUs but overall distribution being the same (Graph 1). When these landform shapes are grouped into broad aggregated landform shapes (Slope, Ridge and Low Slope/Flat), the similarities are further highlighted with the MDA and 20K Area having almost the same composition of broad landform shapes and being approximately 70% Low Slope/Flat (Graph 2).




**Graph 1: Comparison of Detailed Shapes within the MDA and 20K Area**




**Graph 2: Comparison of Broad Shapes within the MDA and 20K Area**




**Rio Tinto**

**Winu Landform Assessment**

**Landform Shapes - MDA and 20K Area**

**FIGURE 3**

LEGEND

MDA

20K Area

Shape

Flat

Peak

Ridge

Shoulder

Spur

Slope

Hollow

Footslope

Valley

Pit

Service Layer Credits:
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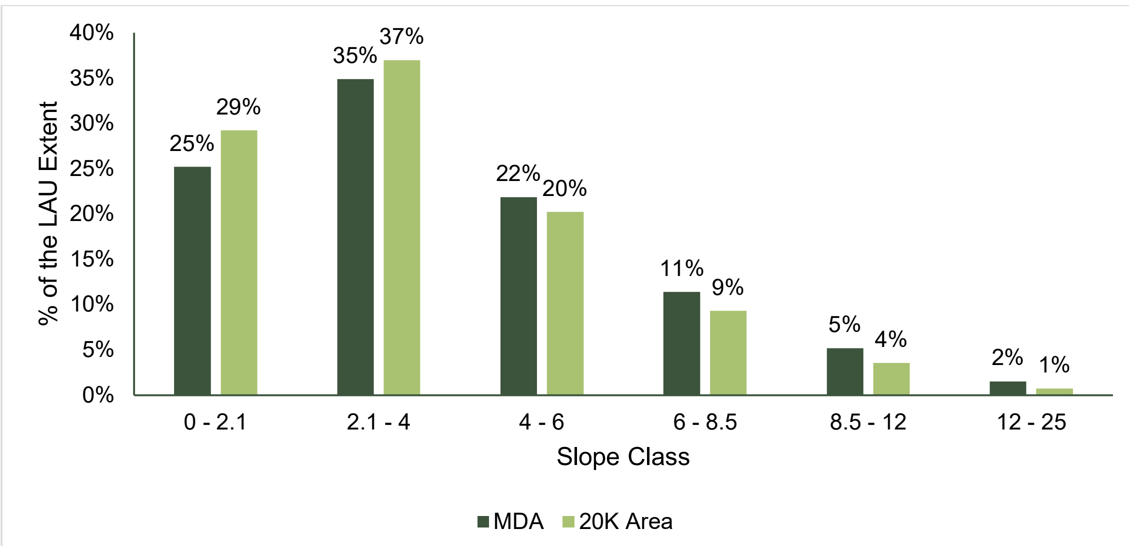
### 3.3.2 Slope

Slope values were calculated as described in Section 2.4.1.2. Lower slope values correspond to flatter terrain, signifying minimal elevation changes, while higher slope values denote steeper terrain, indicating more rapid changes in elevation. The results of the slope analysis have been classified into groups based on the values occurring within the LAUs.

The slope in the MDA and the 20K Area show similar patterns (Graph 3). In both areas, the highest coverage is in Class 0 – 2.1 and Class 2.1 – 4. The MDA has a slightly higher percentage coverage in steeper slope classes (Classes 4 – 6, 6 – 8.5, 8.5 – 12 and 12 – 25) compared to the corresponding classes in the 20K Area. Both areas exhibit a decrease in coverage as slope steepness increases.

Overall, the slope analysis indicates only small differences (up to 4%) between the two areas.

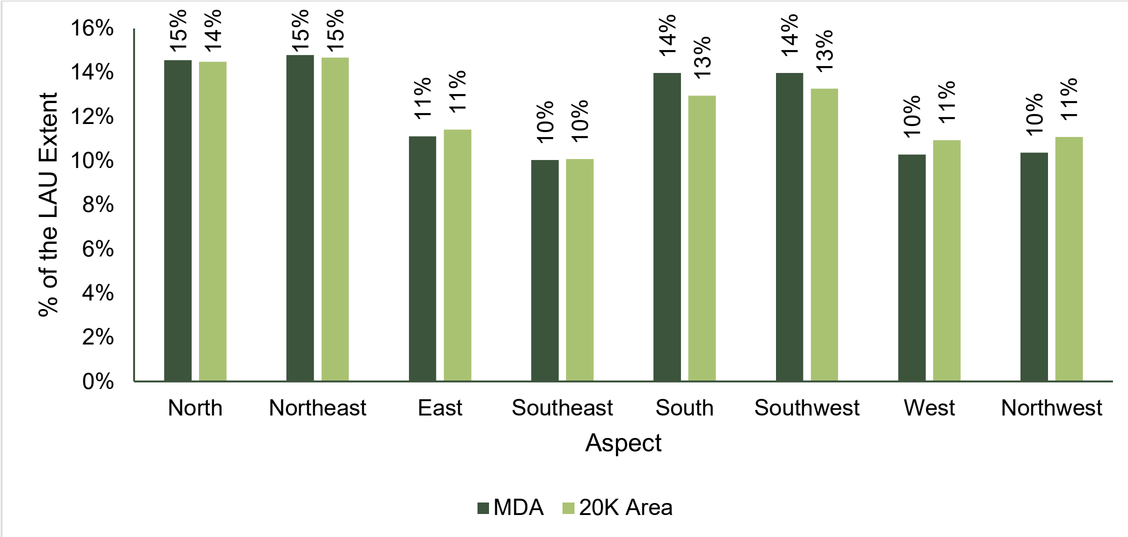



**Graph 3: Comparison of Slope within the MDA and 20K Area**

### 3.3.3 Aspect

Aspect was determined as described in Section 2.4.1.3. Flat areas are excluded from the analysis of slope aspect. Graph 4 provides a summary of aspect values and their respective coverage percentages in the 20K Area and MDA.

The results show a high degree of similarity in terms of aspect across the 20K Area and MDA with only up to 1% difference across each of the aspects (Graph 4). The north, northeast, south and southwest aspects had the highest coverage in both LAUs indicating that the dune ridges generally ran from west-northwest to east-southeast, however the spread of results across all aspects indicates there is variability in the orientation of the dunes in each area (i.e. some dunes are oriented differently and there is curvature in some dunes).




**Graph 4: Comparison of Aspect within the MDA and 20K Area**

### 3.3.4 Dune Ridgelines Over Time

A visual assessment of imagery from Landsat for 2018 and 2023 was undertaken to assess whether changes to the position or extent of the dune ridgelines within the MDA were evident over the five year period. There was no visual evidence of changes to the landforms visible in the MDA (Plate 2).

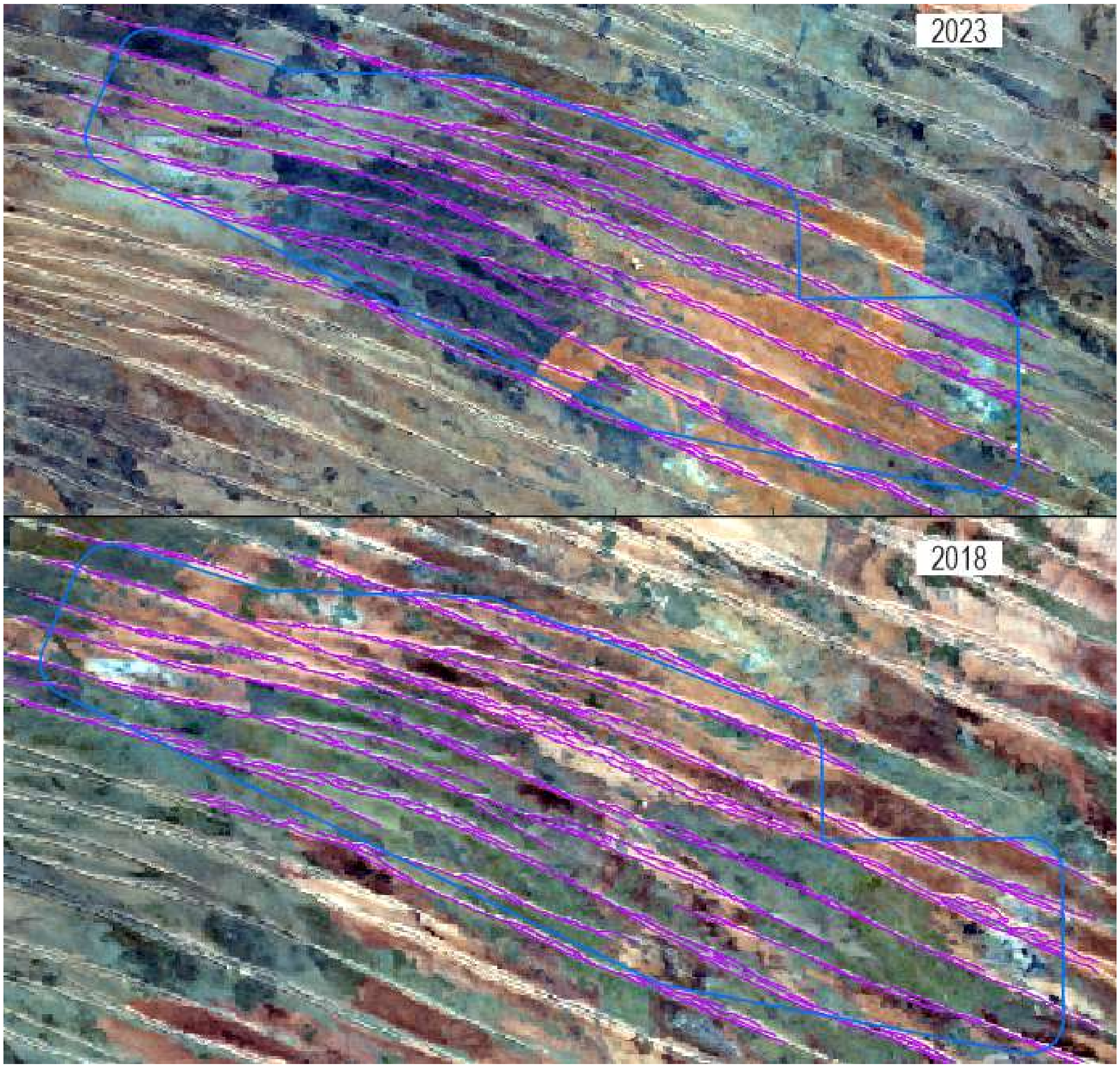



**Plate 2: Visual Comparison of Dune Ridgelines between 2023 and 2018**

### 3.3.5 Wider Great Sandy Desert

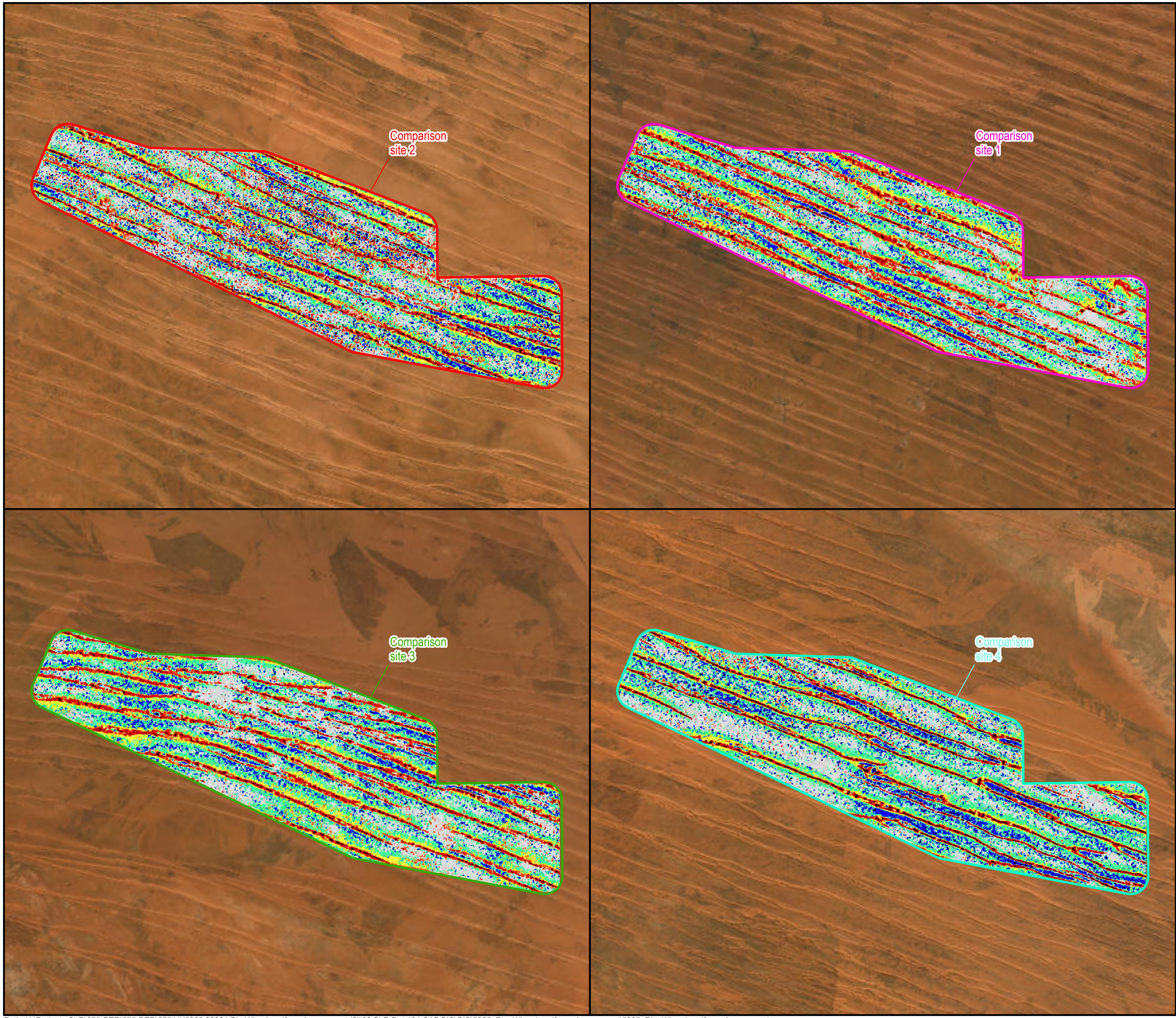
Four additional areas (comparison sites) were selected in the Great Sandy Desert outside the 20K Area to crosscheck the suitability of the 20K Area and to provide additional regional context (Figure 2). The size, shape and orientation of the comparison sites are the same as the MDA. The comparison sites were selected by looking for visually similar landforms in the north, east, west and south of the MDA, with the aim of capturing linear desert dune landforms without water bodies or other significant features that create bias in the analysis.

Landform shapes were similar across the four comparison sites (Figure 4, Graph 5). There is greater similarity in landform shapes between the four comparison sites than between the comparison sites and the 20K Area. This is due to the 20K Area being selected based only on distance around the MDA, and the extent of the 20K Area being greater than the extent of each of the comparison sites, both of which result in the 20K Area capturing a greater variety and variability in the landforms. Note that shapes with <5% coverage for all areas have been removed from the graphs to simplify the results, these shapes were pit, hollow, peak and spur.

Apart from comparison Area 2, the slopes across the 20K Area and the comparison areas follow a similar pattern to that observed for the MDA and the 20K Area, with the highest coverage in Class 0 – 2.1 and Class 2.1 - 4 and a decrease in coverage with increasing slope steepness (Graph 6). Comparison Area 2 differs in that it has a lower coverage in Class 0 – 2.1 than in Class 4 – 6. Comparison Areas 2 and 4 display a lower proportion of gentler slopes than the other areas, with comparison Area 2 showing the greatest differences, namely 11% less coverage in Class 0 – 2.1 and 7% less coverage in Class 2.1 - 4 compared with the 20K Area.

The results show a high degree of similarity in terms of aspect across the four comparison areas and the 20K Area with the maximum difference in coverage being 4% for the northern aspect in the 20K Area and comparison Area 3 (Graph 7). Some variability in the orientation of the dunes is present across each of the areas as evidenced by the spread of results across all aspects; this is relatively consistent across all four comparison areas and the 20K Area.

The morphology results for the four comparison areas show dunal landforms with similar characteristics to those in the MDA are present up to 70 km away from the MDA. Consideration of the variability in results for the four comparison areas and the 20K Area indicates that the 20K Area includes a representative sample of the dunal landforms in the region and can thus be used in assessing the significance of the linear dunes in the MDA.




**Rio Tinto**

**Winu Landform Assessment**

**Comparison sites**

**FIGURE 6**

LEGEND

- Comparison site 1
- Comparison site 2
- Comparison site 3
- Comparison site 4

Geomorphology

- Flat
- Peak
- Ridge
- Shoulder
- Spur
- Slope
- Hollow
- Footslope
- Valley
- Pit

Service Layer Credits:
Earthstar Geographics,SLIP

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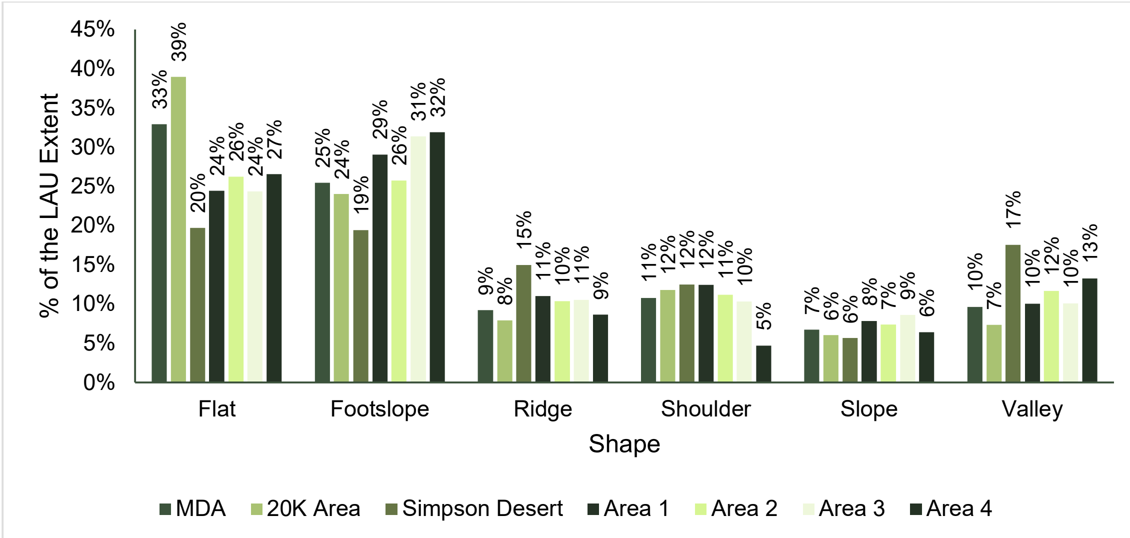
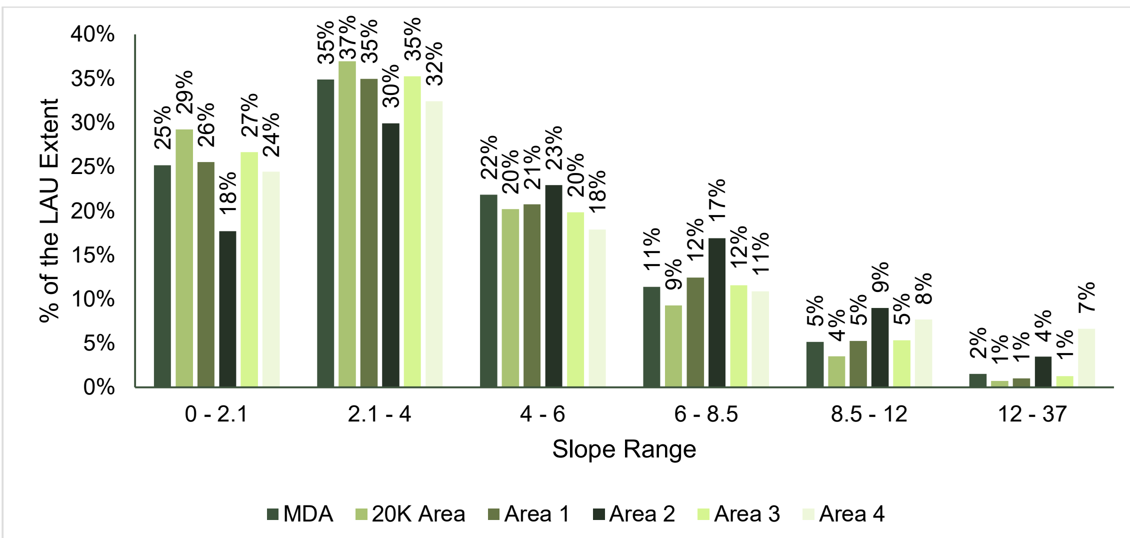
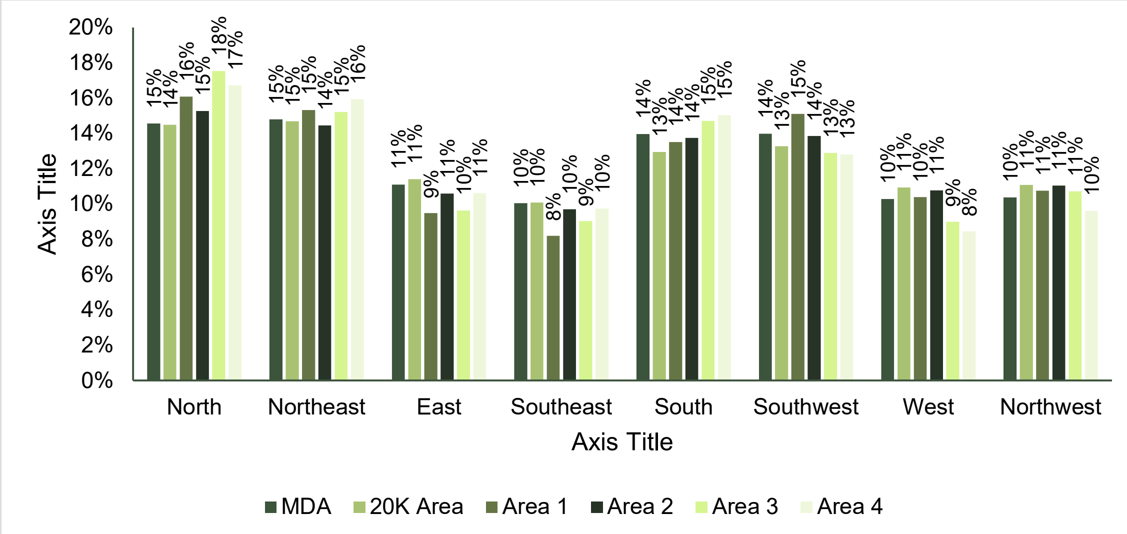



**Graph 5: Comparison of Landform Shape within the MDA, 20K Area and Four Comparison Areas**




**Graph 6: Comparison of Landform Slope within the MDA, 20K Area and Four Comparison Areas**




**Graph 7: Comparison of Landform Aspect within the MDA, 20K Area and Four Comparison Areas**

## 3.4 Ecology

### 3.4.1 Broad Vegetation Types

Mapping of pre-European vegetation in Western Australia was completed on a broad scale (1:1,000,000) by Beard (1976). These vegetation types were later refined by Shepard et al. (2002) resulting in 819 vegetation types.

The MDA occurs wholly within one broad vegetation type, Great Sandy Desert_134. Three broad vegetation types occur within the 20K Area however 99% of the area is identified as Great Sandy Desert_134. Representation of these broad vegetation types within the LAUs is summarised in Table 4.

**Table 2: Extent of Vegetation Types within the MDA and 20K Area**

| Vegetation Type | Vegetation Description | Structure Description | MDA | 20K Area |
|---|---|---|---|---|
| Great Sandy Desert_41 | Wattle, teatree & other species *Acacia* spp. *Melaleuca* spp. | Scrub, open scrub or sparse scrub | - | 1,112 ha<br>0.4% |
| Great Sandy Desert_134 | - | Sparse low tree-steppe / Sparse shrub-steppe | 20,407 ha<br>100% | 285,230 ha<br>98.9% |
| Great Sandy Desert_178 | Hummock grassland *Triodia* spp. | Grass-steppe | - | 1,926 ha<br>0.7% |

### 3.4.2 Indexes

#### 3.4.2.1 NDVI

NDVI values range between -1 and +1. Higher positive values indicate healthy, dense vegetation, while lower or negative values suggest non-vegetated surfaces such as water or barren land.

Due to the unique geographical characteristics of the Great Sandy Desert, the outcomes of the NDVI were categorised into two primary classifications: vegetated areas and non-vegetated areas. The vegetation spectrum spans from 0.2 to 1, incorporating various vegetation types such as shrubs, grassland, sparse vegetation, and dense vegetation.

Both the MDA and the 20K Area had the same percentages of vegetation coverage in 2023.

#### 3.4.2.2 NDWI

NDWI uses the differences in reflectance between the near-infrared radiation (NIR) and green bands. Water bodies typically exhibit higher NDWI values, exceeding 0.5. Whereas, vegetation is characterized by lower reflectance in the NIR band, tends to have smaller NDWI values. Built-up features, which may have varied spectral characteristics, generally yield positive values ranging between zero and 0.2.

The NDWI values correspond to the following ranges:

- 0.2 to 1 – water surface
- 0.0 to 0.2 – flooding, humidity
- -0.3 to 0.0 – moderate drought, non-aqueous surfaces
- -1 to -0.3 – drought, non-aqueous surfaces.

The NDWI for both LAUs was within the ‘drought, non-aqueous surfaces’ category. Given the location of the study areas within the Great Sandy Desert, the results align with the environmental characteristics of the broader region.

#### 3.4.2.3 NDMI

NDMI values range from -1 to 1. NDMI provides insights into the moisture status of vegetation. Negative values, approaching -1, typically indicate barren soil or areas with little vegetation moisture. Values close to zero (-0.2 to 0.4) suggest water stress within vegetation, reflecting lower moisture content. Conversely, high positive values (approximately 0.4 to 1) are indicative of a lush canopy with ample moisture, signifying healthy vegetation without water stress. NDMI is typically used to assess drought conditions, monitor vegetation health, and assist in environmental studies related to water content.

The results indicate bare soil and vegetation under water stress within both LAUs.

### 3.4.3 Ecological Surveys

A summary of Western Botanical’s *Interim Consolidated Detailed Flora and Vegetation Assessment for the Winu Project* (2023) and Biota’s Winu Terrestrial Fauna Interim Consolidation Report (2023) is provided to give the ecological context of the MDA and wider surrounds.

#### 3.4.3.1 Flora and Vegetation

Desktop assessment identified 35 conservation significant flora species occurring within the survey area and within 100 km of the proposed Winu Mine and associated infrastructure. Eleven of these were considered likely to occur and eight were considered possible. No

Priority Ecological Communities (PECs) or Threatened Ecological Communities (TECs) were identified.

The field assessments recorded 302 flora species, of which 11 are considered Priority species by the Department of Biodiversity, Conservation and Attractions (DBCA). Table 3 provides the Priority species recorded, and their distribution based on Florabase records.

**Table 3: Priority Species Recorded within the Winu Survey Area**

| Species | Listing | Distribution (Western Australian Herbarium 1998–) |
|---|---|---|
| *Goodenia hartiana* | P2 | Recorded over a 240 km north-south area east of Marble Bar |
| *Bonamia oblongifolia* | P3 | Recorded along the coast over a distance of approximately 120 km from Broome to Port Hedland |
| *Comesperma sabulosum* | P3 | Recorded over a distance of 500 km between Fitzroy Crossing and Newman extending east into the Northern Territory |
| *Corynotheca asperata* | P3 | Scattered records over a distance of approximately 450 km extending east from Marble Bar to the Northern Territory |
| *Dasymalla chorisepala* | P3 | Scattered records over a distance of approximately 100 km inland between Broome and Port Hedland |
| *Indigofera ammobia* | P3 | Recorded across inland northern Western Australia from Port Hedland to Fitzroy Crossing |
| *Synostemon arenosus* | P3 | Recorded from Newman to Marble Bar extending east into the Northern Terrritory |
| *Terminalia kumpaja* | P3 | Recorded from Eighty Mile Beach to Broome |
| *Tribulopis marliesiae* | P3 | Scattered records from Eighty Mile Beach to Broome with one record approximately 200 km inland of Eighty Mile Beach |
| *?Brachyachne anisocarpa* | New Taxon – considered to be P1 by DBCA | N/A |

All recorded Priority flora species have additional records and a distribution outside of the Winu Project Area (Western Australian Herbarium 1998–). There is currently no record for *Brachyachne anisocarpa* listed on FloraBase, however, Albrecht and McLay (2022) detailed a patchy distribution of the species across Western Australia and the Northern Territory.

Eighteen Vegetation Associations have been identified occurring across five broad floristic types (Table 4).

**Table 4: Broad Floristic Types within the Winu Project Area**

| Broad Floristic Type | Proportion of the Winu Survey Area |
|---|---|
| Hummock grasslands | 0.2% |
| Interdunal sand plains | 74.1% |
| Sand dunes and associated swales | 13.0% |
| Stony rises and gentle outcroppings | 11.1% |
| Triodia hummock grassland | 0.4% |
| Ungrouped | 1.2% |

Most of the vegetation across the Winu Survey Area is considered to be in Excellent condition except for cleared tracks and drill pads.

Western Botanical (2023) note that the flora and vegetation in the Winu Survey Area are considered typical of the Great Sandy Desert Bioregion and gave no indication that any flora species was endemic or restricted to the MDA.

#### 3.4.3.2 Fauna

The field assessment recorded 157 species including 30 mammals, 59 birds, 72 reptiles and one amphibian (Biota 2023). Seven fauna habitats were identified within the Winu Survey Area (Biota 2023):

- Shrub and spinifex on sandplain
- Inland sand dune
- Gravelly lateritic rises
- Clayey sandplain with termitaria
- Disturbed/cleared
- Ephemeral claypan
- Rock outcropping.

The ‘shrub and spinifex on sandplain’ habitat is the dominant habitat, accounting for 73% of the area.

Eight conservation significant species were recorded within the Winu Survey Area with an additional seven likely to occur within 40 km. Key conservation significant fauna species recorded or likely to utilise terrestrial habitat within the MDA include:

- Bilby (*Macrotis lagotis*) – Vulnerable
- Brush-tailed Mulgara (*Dasycercus blythi*)– Priority 4
- Northern Marsupial Mole (*Notoryctes caurinus*) – Priority 4
- Western Pebble-mound Mouse (*Pseudomys chapmani*) – Priority 4
- Dampierland Plain Slider (*Lerista separanda*) – Priority 2
- Oriental Plover (*Charadrius veredus*) – Migratory
- Oriental Pratincole (*Glareola maldivarum*) – Migratory
- Northern Quoll (*Dasyurus hallucatus*) – Endangered
- Spectacled Hare-wallaby (*Lagorchestes conspicillatus leichardti*) – Priority 4

- Black-footed Rock-wallaby (*Petrogale lateralis lateralis*) – Endangered
- Grey Falcon (*Falco hypoleucos*) – Vulnerable
- Little Curlew (*Numenius minutus*) – Migratory

Biota (2023) consider all of the species listed above are also likely to utilise habitats outside of the Winu Survey Area.

Overall, the composition and diversity of the fauna assemblage recorded from the Winu Survey Area is similar to that documented for the habitats occurring in the surrounding locality (Biota 2023). The habitats present within the Winu Survey Area were also determined to be well represented in the locality and regionally. Biota gave no indication that any fauna species was endemic or highly restricted to the MDA.

## 3.5 Simpson Desert

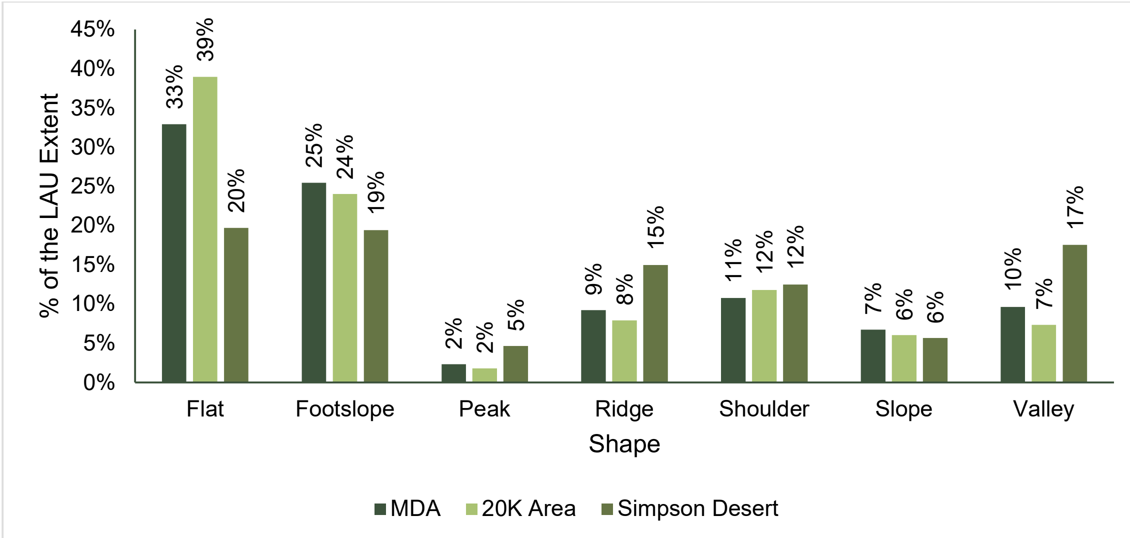
To evaluate the dunes in a national context, a comparison site was selected in a desert outside of Western Australia. A 90,000 ha area in the Simpson Desert with linear dunes was selected from visual assessment of imagery. Morphological analysis was completed for this area and results were compared with morphological assessment results from the MDA (Figure 1).

### 3.5.1 Morphology

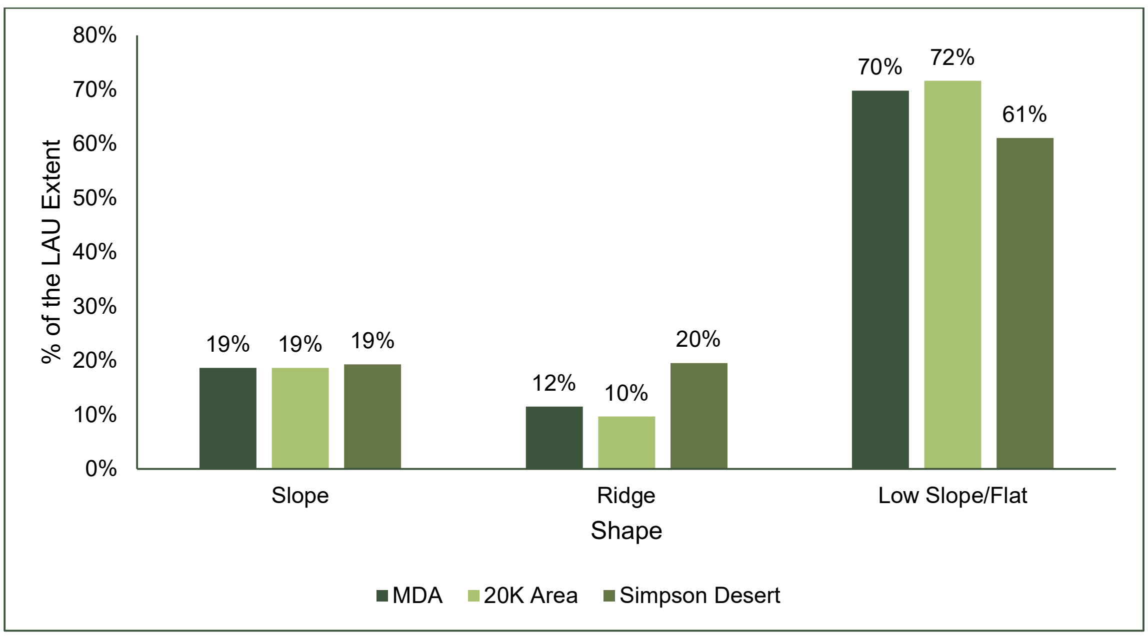
#### 3.5.1.1 Shape

Mapping shows variation of the detailed landform shapes between the three LAUs (Graph 8) with the shape of the landform in the 20K Area and the MDA being much flatter on average than the Simpson Desert (Figure 5). Coverage across the most common shapes was much more evenly distributed in the Simpson Desert than that of the MDA and 20K Area, which both had >50% of the area classified as two shapes (footslope and flat). Note that shapes with <5% coverage for all three LAUs have been removed to simplify results, these shapes were pit, peak and spur.

However, when these landform shapes are grouped into broader landform shapes (slope, ridge and low slopes/flat), the three areas are very similar having almost the same composition of broad landform shapes, overall, the Simpson Desert has more ridges than the MDA and 20K Area (Graph 9).




**Graph 8: Comparison of Detailed Landform Shape within the MDA, 20K Area and Simpson Desert**



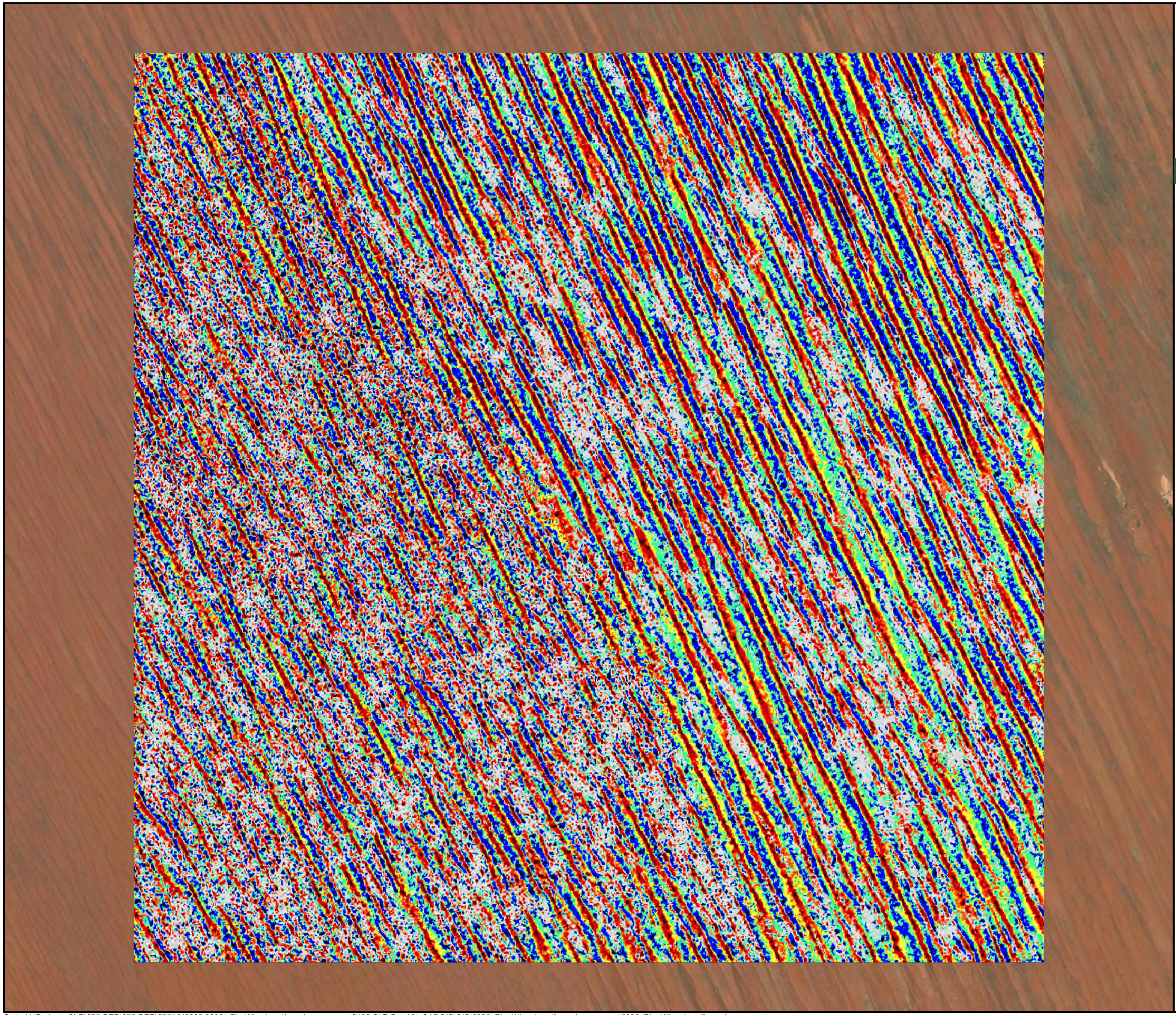

**Graph 9: Comparison of Broad Landform Shape within the MDA, 20K Area and Simpson Desert**

**Rio Tinto**

**Winu Landform Assessment**

**Landform Shape**
**Simpson Desert**

**FIGURE 5**



LEGEND

Shape

- Flat
- Peak
- Ridge
- Shoulder
- Spur
- Slope
- Hollow
- Footslope
- Valley
- Pit

Service Layer Credits:
Earthstar Geographics,SLIP

0 2.5 5 Kilometers

| | |
|---|---|
| Coordinate System: | GDA 1994 MGA Zone 53 |
| Scale: | 1:179,670 at A4 |
| Project Number: | 5965 |
| Date Drawn: | 11-Jan-2024 |
| Drawn by: | EC |
| Reviewed by: | FB |

SLR



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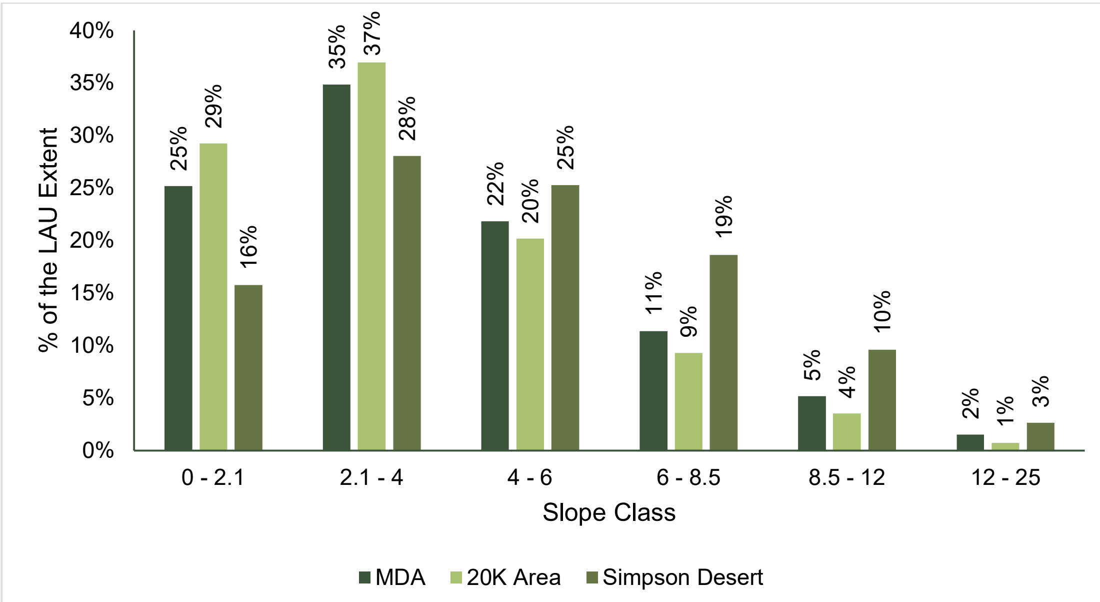
#### 3.5.1.2 Slope

In all three areas (the MDA, 20K Area and the Simpson Desert), coverage is highest in Class 2.1 – 4, with coverage decreasing for steeper slope classes (Classes 4 – 6, 6 – 8.5, 8.5 – 12 and 12 – 25) (Graph 10). Compared with the MDA and the 20K Area, the Simpson Desert has a lower percentage coverage in the flatter classes (Classes 0 – 2.1 and 2.1 – 4) and higher percentage coverage in steeper classes (Classes 6 – 8.5, 8.5 – 12 and 12 – 25).

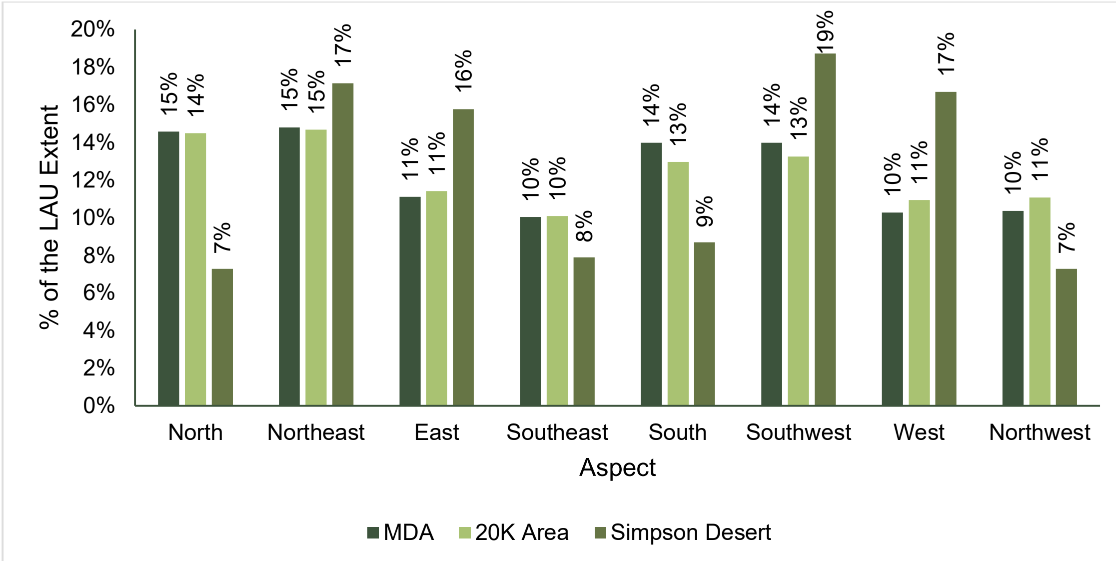



**Graph 10: Comparison of Slope within the MDA, 20K Area and Simpson Desert**

#### 3.5.1.3 Aspect

Graph 11 provides a summary of aspect values and their respective coverage percentages in the 20K Area, MDA and Simpson Desert, noting that flat areas have been excluded from the analysis of the slope aspect.

As discussed in Section 3.3 the results show a high level of similarity in terms of aspect across the 20K Area and MDA with only up to 1% difference across each of the aspects. The north, northeast, south and southeast aspects had the highest coverage in both LAUs indicating that the dune ridges generally run from west-northwest to east-southeast however the relatively high coverage for all aspects indicates some variability in the orientation of the dunes in the MDA (i.e. there is some curvature in the orientation of the ridgelines and associated dune faces, particularly apparent where several ridgelines meet). The Simpson Desert had the highest coverage in northeast, east, southwest and west aspects indicating that the dune ridges generally run from north-northwest to south-southeast. The relatively low coverage across other aspects indicates the degree of variability of the dune orientation is much lower than in the MDA and 20K Area.




**Graph 11: Comparison of Aspect within the MDA, 20K Area and Simpson Desert**

#### 3.5.1.4 Dune Ridgelines

Visual analysis of the dunes shows significant differences between the dunes in the MDA compared with those in the Simpson Desert. Plate 3 shows the Simpson Desert on the left and the MDA on the right with red indicating a ridge and blue indicating a slope. These images provide visual verification of the differences between the MDA and Simpson Desert dunes as identified in the previous sections. The dunes in the MDA are longer, exhibit more interconnections and branching, have greater spacing (typically between 200 m and 2000 m), and have more variability in orientation than the Simpson Desert dunes. The Simpson Desert dunes are highly variable in length but generally short in comparison to those in the MDA, exhibit less interconnections with no evidence of branching, are closer spaced (typically between 100 m and 1000 m) and have low variability in orientation.

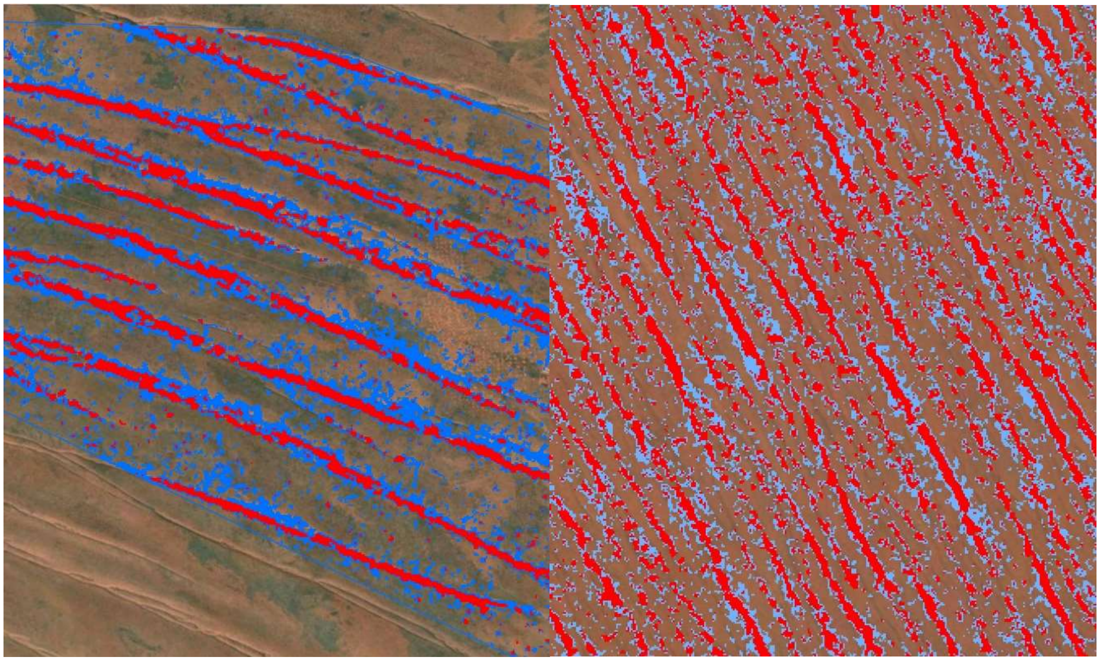


**Plate 3: Comparison of Ridgelines within the MDA (left) and Simpson Desert (right) (Scale 1:40000)**

# 4.0 Discussion

## 4.1 Variety

The EPA's criterion for variety is, "*the landform is a particularly good or important example of its type and/or the landform is not well represented at a local, regional or national scale or differs from other examples at these scales*".

Linear and reticulate dunes are well represented across the Little Sandy Land System and are identified as a key feature of the system which occurs across an extent of 2,102,527 ha. A significant proportion of the landforms in the MDA and 20K Area form a part of this broader land system.

The morphological analysis provided data about the shape, slope and aspect of the landforms. Comparison of these data for the landforms in the MDA with data for landforms in the 20K Area and the four comparison areas in the Great Sandy Desert showed variations between the areas (Section 3.3) but did not identify any characteristics to indicate that the dune landforms in the MDA are significantly different to those in the 20K Area and more broadly those in the Little Sandy Land System.

Comparison of the morphological data for the MDA, 20K Area and the Simpson Desert (Section 3.5.1) allows the significance of the variations between the MDA and the 20K area to be assessed. The area selected in the Simpson Desert is located 1,568 km from the MDA, is subject to different environmental processes and is not part of the Little Sandy Land System. The Simpson Desert landforms show distinct differences in landform shape, slope steepness and aspect compared with the MDA and 20K Area. Examples of these differences include:

- Lower proportion of flat areas in the Simpson Desert (20% in the Simpson Desert, 33% in the MDA, 39% in the 20K Area)

- Lower proportion of footslopes in the Simpson Desert (19% in the Simpson Desert, 25% MDA, 24% 20K Area)
- Higher proportion of ridges (15% in the Simpson Dessert, 9% MDA, 8% 20K Area)
- Overall steeper slopes (refer Graph 10).

The above examples show that the degree of variation between landforms in the MDA and the 20K area is much less than the variation between these areas and a different system, indicating that the observed variations between the MDA and the 20K Area are not significant. The analysis, therefore, demonstrates that the landforms in the MDA are well represented at a local and regional scale.

Given dune landforms with similar characteristics to those in the MDA are well-represented at a local and regional scale, the landforms in the MDA are not considered to represent landforms that are better examples or any more important than those elsewhere in the region. Therefore, the landforms within the MDA are not considered to meet the EPA's criteria for variety.

## 4.2 Integrity

The EPA's criterion for integrity is, "*the landform is intact, being largely complete or whole and in good condition*".

The MDA is located in a remote area with very limited previous disturbance to the area, the closest town is located approximately 150 km from MDA and the closest operational major project is Woodie Woodie, located approximately 116 km southwest and Telfer, located approximately 120 km southeast of the MDA. Vegetation across the MDA was considered to be in Excellent condition with the exception of cleared access track and exploration drill pads and associated activities (Western Botanical 2023). Western Botanical noted that vegetation was "*Pristine or nearly so, no obvious signs of damage cause by human activities since European Settlement*".

Analysis of the dune ridges (Section 3.3.4) showed no degradation or movement of the dunes over a 5-year period.

Given the limited disturbance and lack of evidence of degradation, the landforms in the MDA are considered to be intact, whole and in good condition, therefore meeting the EPA's criterion for integrity. Based on review of aerial imagery, there appears to be limited human disturbance within the wider 20K Area and beyond indicating majority of the landforms across the region are likely to meet the EPA criterion for integrity.

## 4.3 Ecological Importance

The EPA's criterion for ecological importance is, "*the landform has a distinctive or exclusive role in maintaining existing ecological and physical processes and/or the landform supports endemic or highly restricted plants or animals"*.

The landforms within the MDA may contain microhabitats for flora and fauna as a result of the variations in slope, aspect, wind protection, moisture and soils. The analysis identifies morphological variations across the dune landforms within the MDA. However, comparison to the 20K Area and the four comparison areas within the Great Sandy Desert shows that the observed variations are repeated across all of these areas. Comparison of the outputs for the selected area in the Simpson Desert with results for the MDA/20K Area places the MDA/20K results in a national context highlighting that the observed variations between the MDA and the 20K Area are small compared with observed variations between systems. The analysis indicates the characteristics of the landforms in the MDA (e.g. shape, slope, aspect and moisture) are not unique to each dune landform and, therefore, the microhabitats associated within each dune landform are unlikely to be unique. As such, each landform in the MDA is unlikely to provide an exclusive role in maintaining ecological processes.

Western Botanical (2023) and Biota (2023) identified that the flora, vegetation and fauna recorded in the MDA are typical of the local area and region. Fauna habitats and flora distribution were identified to be widespread outside the MDA. No evidence was found that any particular flora or fauna species was endemic or highly restricted to any particular dune landform within the MDA or the dune system in the MDA.

Given, microhabitats associated with the dunes are unlikely to be unique to the dunes in the MDA, and no evidence was found that any particular flora or fauna species is endemic or highly restricted to the MDA, the landforms within the MDA are not considered to meet the EPA's criterion for ecological importance.

## 4.4 Scientific Importance

The EPA's cirterion for scientific importance is, "*the landform provides evidence of past ecological processes or is an important geomorphological or geological site and/or the landform is of recognised scientific interest as a reference site or an example of where important natural processes are operating*".

The dune landforms within the MDA provide a means of evaluating past ecological and geological process. However, there is no evidence to suggest that the dune landforms within the MDA are of particular importance or scientific interest compared to the dune landforms in the 20K Area. Scientific interest within the MDA has been limited to studies associated with the Winu Project.

A geoheritage site has 'geological features considered to be unique and of outstanding scientific and educational value within Western Australia' (Martin 2023). No geoheritage sites have been mapped within the MDA nor within the Great Sandy Desert. The closest geoheritage site is located southwest of the MDA within the Pilbara IBRA Region.

Given that there is no evidence to suggest that the dune landforms within the MDA are of particular importance or scientific interest and there are no known geoheritage sites within the MDA or Greater Sandy Desert, the landforms within the MDA are not considered to meet the EPA's criterion for scientific importance.

## 4.5 Rarity

The EPA's criterion for rarity is, "*the landform is rare or relatively rare, being one of the few of its type at a national, regional or local level*". The results of the morphology analysis allowed for the definition of the dune landforms, highlighting the ridges and slopes of the dunes and the orientation of the dunes. The dune landforms are numerous and well represented at both local and regional scales, and therefore are not considered rare, relatively rare or being one of a few of its type at any scale. The landforms in the MDA are, therefore, not considered to meet the EPA's criterion for rarity.

## 4.6 Conclusion

The analysis shows that the dune landforms in the MDA are well-represented at local and regional scales and are not distinct from those in the broader Great Sandy Desert. The similarities in shape, slope, aspect and moisture between the landforms in the MDA and those in the 20K Area and the four comparison areas, indicate that any microhabitats that are present in the dune landforms of the MDA are likely to also be present in the dune landforms throughout the region. In addition, ecological data do not suggest that any flora or fauna species is likely to be endemic or highly restricted to the MDA. No geoheritage sites have been identified in the MDA and there is no evidence that the landforms in the MDA are of particular scientific interest compared with those in the 20K Area. The landforms in the MDA, therefore, do not meet the EPA landform significance criteria for variety, ecological importance or scientific importance.

The landforms in the MDA are considered to meet the EPA's criterion for integrity. However, given the remote location and limited human disturbance, the majority of the landforms across the region are likely to meet the EPA criterion for integrity. The intact nature and integrity of the dune landforms in the MDA is, therefore, not unique to the MDA and is not considered to be a key defining factor in determining the significance of the landforms in the MDA. Social importance of the dunal landforms was not included in the assessment as this aspect will be considered separately by Rio Tinto as part of an assessment of Social Surroundings.

Considering the dune landforms of the MDA in a local and regional context, it is concluded that the landforms in the MDA are not significant according to the EPA criteria for the significance of landforms.

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# 6.0 Feedback

At SLR, we are committed to delivering professional quality service to our clients. We are constantly looking for ways to improve the quality of our deliverables and our service to our clients. Client feedback is a valuable tool in helping us prioritise services and resources according to our client needs.

To achieve this, your feedback on the team's performance, deliverables and service are valuable and SLR welcome all feedback via https://www.slrconsulting.com/en/feedback. We recognise the value of your time and we will make a $10 donation to our 2023 Charity Partner - Lifeline, for every completed form.

Making Sustainability Happen