BONNEY DOWNS WIND GENERATION HUB:

DESKTOP SOIL AND LANDFORM ASSESSMENT

Fortescue Limited

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1 INTRODUCTION

1.1 Project Background

Pilbara Energy (Generation) Pty Ltd (PEG), a wholly owned subsidiary of Fortescue Limited (Fortescue), is proposing to develop the Bonney Downs Wind Farm (Bonney Downs). The project will involve the installation of 200 wind turbines, two substations and associated transmission infrastructure. Bonney Downs will also include battery energy storage systems, associated supporting infrastructure, and a series of access roads and corridors from electrical and transmission cabling.

Bonney Downs is located approximately 10km west of Nullagine Town and adjacent to BC Iron's Nullagine Project, in the Pilbara region of Western Australia (Figure 1). The area associated with Bonney Downs is referred to as the Survey area in this document. This area spans across Bonney Downs, Roy Hill and Hillside Pastoral Leases, with Fortescue currently holding a selection of live tenure and a large number of pending tenure over the Survey area. Much of the live tenure occurs to the south, intersecting the proposed transmission corridor, whilst few live tenements are currently available in the wind farm hub area.

The total size of the Survey area is approximately 96,869 ha, and the indicative disturbance footprint (IDF) is 2,043ha. Associated live tenements are outlined in Table 1, with numerous pending tenure over the majority of the Survey area.

Table 1: Live tenure associated with Bonney Downs.

Tenure	Status	Holder
L 46/49	Live	Chichester Metals Pty Ltd
L 46/74	Live	FMG Nullagine Pty Ltd
L 46/80	Live	FMG Nullagine Pty Ltd
L 46/82	Live	FMG Nullagine Pty Ltd
L 46/83	Live	FMG Nullagine Pty Ltd
L 46/84	Live	FMG Nullagine Pty Ltd
L 46/85	Live	FMG Nullagine Pty Ltd
L 46/93	Live	FMG Nullagine Pty Ltd
L 46/95	Live	FMG Nullagine Pty Ltd
L 46/114	Live	FMG Nullagine Pty Ltd
L 46/118	Live	FMG Nullagine Pty Ltd
L 46/119	Live	FMG Nullagine Pty Ltd
L 46/139	Live	Alinta Energy Transmission (Chichester) Pty Ltd

To support the Environmental Impact Assessment (EIA), Fortescue hopes to thoroughly understand the environmental factors that may be impacted by its developments. The size and scale of these impacts must be fully understood to allow for the development of the EIA. To meet this requirement, Fortescue is undertaking a range of Surveys and studies to better understand the environment.

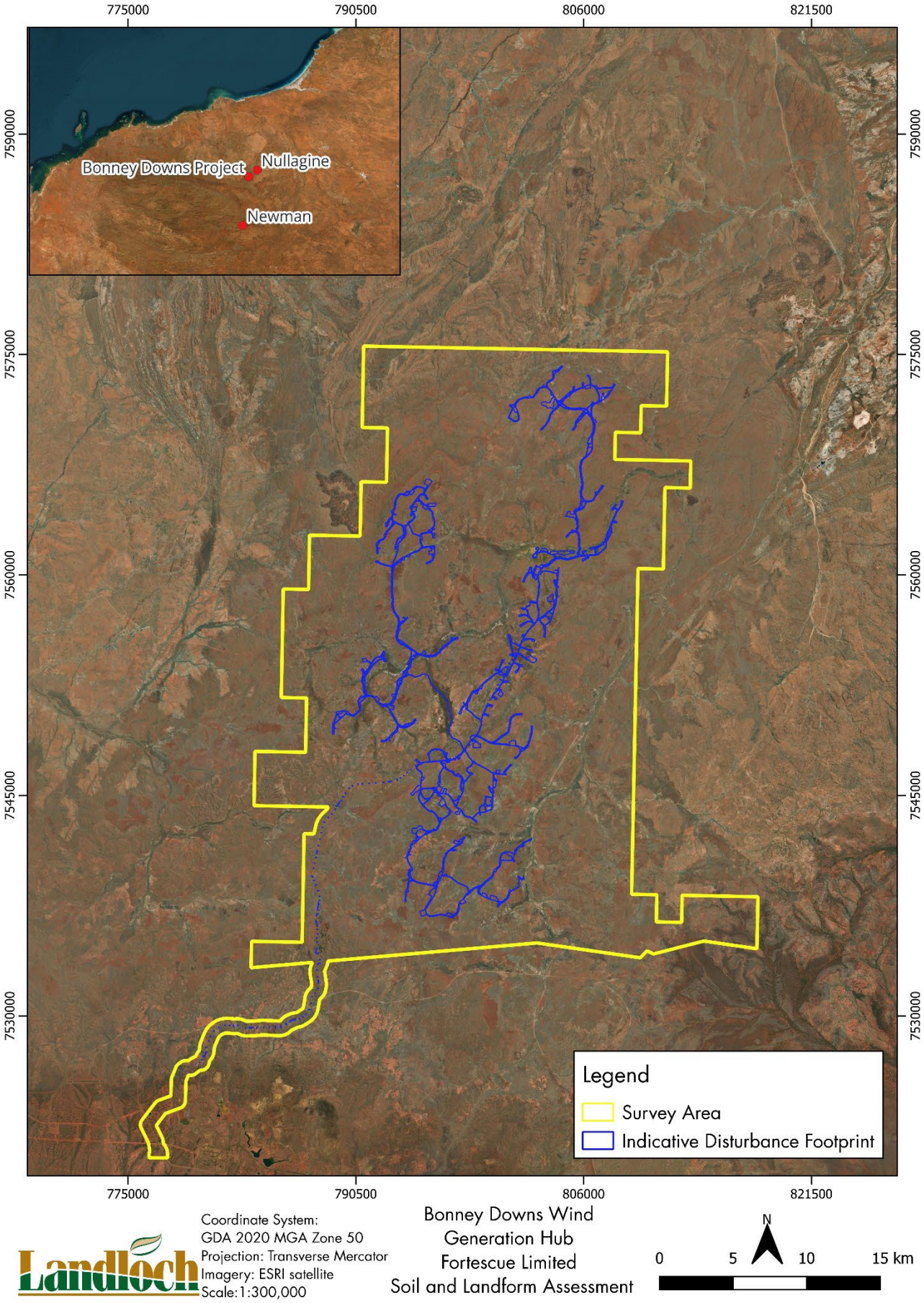

Figure 1: Location of Bonney Downs.

1.2 Scope of work

Fortescue has engaged Landloch Pty Ltd (Landloch) to complete a soil and landform assessment of Bonney Downs. The aim of the assessment is to characterise the existing surface soils and landforms at Bonney Downs, to identify any potentially problematic characteristics, and to identify any landforms of potential significance. Included in this is an assessment of Acid Sulfate Soils (ASS). As part of the soil and landform assessment, the following activities have been completed:

- Review of relevant site information, land systems, and regional soil information;
- Desktop analysis of the landforms present at Bonney Downs and assessment of their potential significance;
- Desktop analysis of the soils present at Bonney Downs and an assessment of the potential impact from the proposed development;
- Preliminary mapping of soils and landforms based on desktop information; and
- Assessment of Potential Acid Sulphate Soil (PASS).

Following this desktop assessment, a field investigation will be undertaken to ground-truth the preliminary soil and landform mapping.

1.3 EPA Objective

The Environmental Protection Authority (EPA) requirements to be addressed for Bonney Downs include two Environmental Factors:

- Terrestrial Environmental Quality (EPA 2016); and
- Landforms (EPA 2018).

Both Environmental Factors have been identified as having a possibility of impact. The Terrestrial Environmental Quality factor may require an in-field assessment to establish baseline soil quality values. The Landforms factor can be progressed at the desktop level but may require an in-field assessment to ground-truth landforms of potential significance identified within the review.

1.3.1 Terrestrial Environmental Quality

The WA EPA objective for the Terrestrial Environmental Quality factor is, '*To maintain the quality of land and soils so that environmental values are protected*' (EPA, 2016).

The Terrestrial Environmental Quality factor is aimed at understanding the existing environmental values and the potential impacts to these values as a result of the proposed activity.

The focus of this project is to address the soil quality component of this factor; specifically, how changes to soil quality impact environmental values. The broad requirements include the collection of baseline (pre-disturbance) information on soil quality, and using this data, if required, to determine the mitigation, management, and rehabilitation practices to be adopted at a local scale.

1.3.2 Landforms

The WA EPA objective for the Landforms factor is '*To maintain the variety and integrity of significant physical landforms so that environmental values are protected' (EPA, 2018).*

To address the landform component, a review of existing information has been undertaken to assess if landforms with any of the six criteria are likely to be present at Bonney Downs (Table 2). Landforms identified as potentially significant may require in-field verification.

Table 2: Criteria for determining whether a landform is significant (EPA 2018).

Criteria	Determination
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 the existing ecological and physical processes; for example, by providing a unique microclimate, source of water flow, or shade. The landform supports endemic or highly restrictive plants or animals.
Scientific importance	The landform provides evidence of past ecological processes or is an important geomorphological or geological site. The landform is of recognised scientific interest as a reference site or an example of where important natural processes are operating.
Rarity	The landform is rare or relatively rare, being one of the few of its type at a national, regional or local level.
Social importance	The landform supports significant amenity, cultural or heritage values linked to its defining physical features.

2 DATA REVIEW

A review of existing data has been undertaken and is provided below. The review focused on understanding both the land characteristics and the potential soil types present by drawing on several sources of data to link soil and landscape morphology. Publicly available data sources and site-specific data sources have been reviewed.

2.1 Land Resources Mapping

Land resources mapping has been conducted across Western Australia at varying levels of intensity. The collation of this information has resulted in the development of soil-landscape mapping for the whole of Western Australia. The scale of mapping varies across the state, with areas split into regions depending on the level of data available at the time of compilation. Mapping is compiled at differing levels of intensity depending

on the region. Land systems mapping is available for the Survey area, based on Tille (2006) and van Vreeswyk *et al.* (2004). This mapping was conducted at level 4 (land systems) with a corresponding scale of 1:250,000.

There are fourteen (14) land systems present within the Survey area, illustrated in Figure 2, and summarised in Table 3. The dominant land system is Rocklea (55%), followed by Bonney (18%). Other minor systems include Wona (8%), McKay (6%), Capricorn (5%) and Robe (5%). The remaining eight land systems each comprise <1% of the Survey area, collectively comprising an area of 3%.

The Rocklea land system consists of basalt hills, plateaux, lower slopes and stony plains that support spinifex grasslands. This system is typically comprised of erosional surfaces and stony slopes with stony soils and shallow loams. Minor gilgai plains and narrow draining floors are present and are associated with clays and shallow loamy duplexes.

The Bonney land system is comprised of low rounded hills and undulating stony plains that support soft spinifex grasslands. Similar to the Rocklea system, this system is typically comprised of erosional surfaces and stony plains. The soils are predominantly calcareous loamy earths and stony soils.

The Wona land system is predominantly comprised of erosional surfaces, comprised of basalt upland gilgai plains supporting tussock grasslands and minor spinifex grasslands. Stony gilgai plains dominate this system resulting in primarily self-mulching cracking clays and stony soils.

The McKay land system is an erosional system that consists of hills, ridges, plateau remnants, and breakaways composed of sedimentary rock Vegetation is predominantly hard spinifex grasslands. Soils are typically stony, with deep loamy duplex soils present.

The Capricorn land system is composed of sandstone hills, ridges, stony foot slopes and interfluves. This land system is dominated by stony soils.

The Robe land system is similarly comprised of erosional surfaces with low plateaux, mesas and limonite buttes supporting spinifex grasslands. The majority of this and system is comprised of stony soils. Soils present within the Robe system are stony soils, deep loamy duplexes and earths, clays and shallow loamy duplexes.

Land systems mapping available for the Survey area includes a description of landform type and abundance. Each of the 14 land systems is comprised of several landform elements, consisting of upper erosional landscapes and lower depositional landscapes. Tables 4–17 provide a detailed breakdown of the landform elements present in each land system, their abundance, and associated vegetation.

A total of 72 individual landform elements are described across the 14 land systems present within the Survey area. Many of these elements consist of comparable landforms in similar locations within the landscape. Comparable landform elements have been consolidated into landform units to facilitate identification and mapping. Table 18 summarises the landform units and associated landform elements described across the fourteen land systems.

Table 3: Land systems of the Survey area

Land system	Area (ha)	% of Survey Area	Soils	Description
Rocklea	53,128	55	Stony soils, red shallow loams, calcareous shallow loams.	Basalt hills, plateaux, lower slopes and stony plains supporting hard and soft spinifex grasslands.
Bonney	17,853	19	Calcareous loamy earths, red loamy earths, Deep and shallow non-cracking clays.	Low rounded hills and undulating stony plains supporting spinifex grasslands.
Wona	7,910	8	Self-mulching cracking clays, deep non-cracking clays.	Basalt upland gilgai plains supporting tussock grasslands and minor spinifex grasslands.
McKay	5,751	6	Stony soils, deep loamy duplex soils, red loamy earths.	Hills, ridges, plateaux remnants and breakaways supporting spinifex.
Capricorn	4,476	5	Stony soils, shallow loams, shallow sands.	Hills and ridges of sandstone and dolomite supporting shrubby spinifex grasslands.
Robe	4,333	4	Stony soils, shallow gravel soils, shallow loams.	Low mesas and buttes supporting soft and hard spinifex grasslands.
Laterite	882	1	Shallow gravely soils, stony soils, shallow sands.	Laterite mesas and gravelly rises and plains supporting mulga shrublands.
Jamindie	632	1	Red-brown hardpan shallow loams, stony soils, red loamy earths.	Stony hardpan plains and rises supporting groved mulga shrublands.
River	501	1	Deep non-cracking clays, red loamy earths, river bed soils.	Active flood plains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and spinifex.
Newman	306	<1	Stony soils, red shallow loams, red shallow sands.	Rugged plateaux, ridges and mountains supporting spinifex grasslands.
Elimunna	294	<1	Red/brown non-cracking clays, self-mulching cracking clays, deep loamy duplexes.	Stony plains on basalt supporting sparse acacia shrublands and patchy tussock grasslands.
Spearhole	275	<1	Red/brown hardpan shallow loams, red loamy earths.	Gently undulating hardpan plains supporting groved mulga shrublands.
Granitic	78	<1	Red shallow sands, stony soils, bare rock.	Rugged granitic hills supporting shrubby hard and soft spinifex grasslands.
Turee	36	<1	Self-mulching cracking clays, red deep loamy duplexes, red shallow loams.	Stony alluvial plains with gilgai surfaces, supporting tussock grasslands.

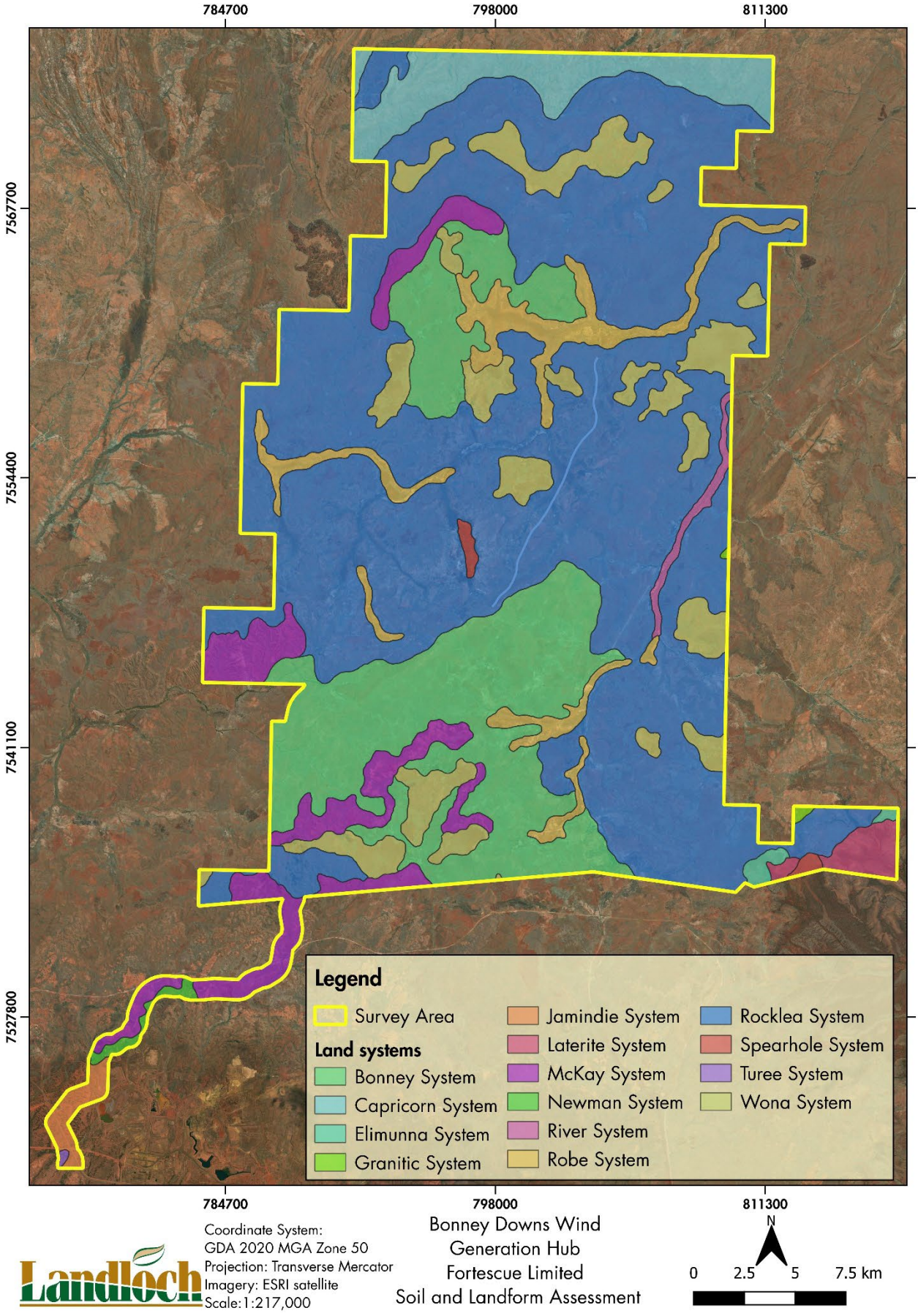

Figure 2: Land systems mapping of the Survey area.

Table 4: Characteristics of the Rocklea system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Hills, ridges, plateaux and upper slopes	65%	Rounded, very gently inclined or undulating crests and plateaux surfaces with moderately inclined to very steep, sometimes benched, upper slopes; surface mantles of very abundant cobbles and pebbles mostly of basalt.	Stony soils (203), red shallow loams (522) and calcareous shallow loams (521).	*Hummock grasslands* of *Triodia wiseana*, T. spp. (hard spinifex) or, less frequently, of *T. pungens* (soft spinifex) with isolated to very scattered shrubs such as *Acacia inaequilatera* (kanji) and *Senna spp*.
2.	Lower slopes	15%	Very gently inclined to gently inclined slopes extending up to 1km downslope from hills. Surface mantles of abundant to very abundant pebbles and cobbles mostly of basalt, also outcrop of basalt.	Red shallow loams (522) and red shallow sandy duplex soils (406).	As for unit 1.
3.	Stony plains and interfluves	10%	Gently undulating to undulating plains, interfluves and low rises up to 1.5 km in extent, surface mantles of abundant to very abundant pebbles and cobbles of basalt and occasionally shale and other rocks.	Calcareous shallow loams (521), red sandy earths (463) and shallow red/brown non-cracking clays (622).	Hummock grasslands of *Triodia wiseana* or, less frequently, *T. pungens* with isolated to very scattered shrubs such as *Acacia inaequilatera*. Occasionally grassy shrublands with *Acacia*, *Senna* and *Eremophila spp*.
4.	Gilgai plains	1%	Level plains up to 500m in extent with gilgai microrelief and variably abundant surface mantles of basalt pebbles and cobbles.	Self-mulching cracking clays (602).	Tussock grassland with *Astrebla pectinata* (barley Mitchell grass), *Eragrostis xerophila* (Roebourne Plains grass) and other perennial grasses.
5.	Upper drainage lines	4%	Narrow headwater valleys with branching drainage tracts mostly <200m wide, unchanneled or with central channels up to 10m wide.	Red shallow sands (423) and calcareous shallow loams (521). Channels with river bed soils (705).	Hummock grasslands of *Triodia wiseana* or *T. pungens* with very scattered to scattered acacia shrubs and occasional *Corymbia hamersleyana* trees.
6.	Drainage floors and channels	5%	Almost level floors rarely more than 400m wide, central tracts with braided channels and stony banks; major trunk channels up to 50m wide.	Red loamy earths (544) with red shallow sandy duplex soils (406) and red/brown non-cracking clays (622).	Scattered to moderately close tall shrublands or woodlands of *Acacia* and *Eucalyptus spp*. with numerous undershrubs and hummock grass understoreys or tussock grass understoreys.

Table 5: Characteristics of the Bonney system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Hills	26%	Low (up to 25m) rounded hills with gently to moderately inclined footslopes, mantles of abundant basalt and other pebbles and rocks, also rock outcrop.	Stony soils (203).	Hummock grasslands mostly of *Triodia pungens* (soft spinifex) occasionally with isolated *Eucalyptus leucophloia* (snappy gum) trees.
2.	Low rises	10%	Undulating rises and stony plains with mantles of common to abundant pebbles of basalt and other pebbles and rocks.	Shallow red/brown non-cracking clays (622).	Hummock grasslands of *T. pungens* with isolated shrubs.
3.	Stony plains	50%	Gently undulating stony plains downslope from units 1 and 2 with mantles of few to abundant pebbles of basalt (occasionally calcrete).	Calcareous loamy earths (542) and red loamy earths (544).	Hummock grasslands of *T. pungens* with isolated acacia shrubs.
4.	Stony gilgai plains	4%	Level clay plains with gilgai micro relief and mantles of common basalt pebbles.	Self-mulching cracking clays (602) or red/brown non-cracking clays (622).	Patchy tusoock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) and other perennial grasses.
5.	Drainage floors	10%	Narrow (<500m wide) floors and minor channels up to 50m wide and incised 2-3m.	Deep red/brown non-cracking clays (622) with minor river bed soils (705).	Hummock grasslands of *T. pungens* and isolated shrubs. Less frequently tall shrublands or woodlands of acacias and eucalypts with prominent ground layer of *T. pungens* or tussock grasses.

Table 6: Characteristics of the Wona system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Low basalt hills	5%	Isolated hills up to 20m high and 500m long, short gently to moderately inclined slopes, surface mantles of abundant or very abundant pebbles and cobbles of basalt.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated to very scattered *Acacia* and *Senna spp*. shrubs. Occasionally *Triodia pungens* (soft spinifex).
2.	Stoney gilgai upland plains	70%	Level to very gently inclined plains up to 4km in extent, gilgai microrelief with surface mantles of many to very abundant pebbles and cobbles of basalt.	Self-mulching cracking clays (602) and some deep red/brown non-cracking clay (622).	Tussock grasslands with *Astrebla pectinata* (barley Mitchell grass), *A. elymoides* (weeping Mitchell grass), *Eragrostis xerophila* (Roebourne Plains grass), *Aristida latifolia* (feathertop three awn), *Eriachne spp*. (wire grass) and *Sida fibulifera* (creeping sida). Also patches of *Acacia xiphophylla* (snakewood) shrublands with understorey of tussock grasses as above and *Senna spp.*
3.	Stony plains and slopes	20%	Very gently inclined plains and short gently inclined to steep benched slopes within unit 2 or at margins of unit 1 or leading to incised drainage (unit 4), surface mantles of abundant to very abundant pebbles and cobbles of basalt.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Hummock grasslands of *Triodia wiseana*, less frequently *T. pungens* with isolated to very scattered (occasionally denser) tall shrubs such as *Acacia inaequilatera* (kanji), *A. aneura* (mulga) and *A. xiphophylla.*
4.	Drainage lines	5%	Narrow (<300m wide), shallow drainage floors and small channels, also more incised channels to 15m wide in narrow valleys with gently inclined to steep stony marginal slopes.	Red deep sandy duplex soils (405), red shallow loams (522) and shallow red/brown non-cracking clays (622).	Scattered to moderately close tall shrublands of *Acacia xiphophylla* or other *acacias* with patchy tussock grass understorey.

Table 7: Characteristics of the McKay system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Hills, ridges and plateaux remnants	60%	Rounded hills and ridge crests, level to gently inclined plateaux surfaces, moderately inclined to very steep upper slopes; surface mantles of very abundant pebbles, cobbles and stones of shale, chert, ironstone, sandstone or dolomite, also rock outcrop; relief up to 100m.	Stony soils (203).	Hummock grasslands of *Triodia lanigera, T. wiseana* (hard spinifiex) with isolated to scattered *Acacia spp.* shrubs or *Eucalyptus leucophloia* (snappy gum) trees.
2.	Breakaways	2%	Indurated mesa caps of ironstone or laterite with vertical breakaway faces up to 15m high over weathered parent rock and with short, moderately inclined to steep slopes below; mantles of very abundant ironstone gravels and other rocks.	Stony soils (203).	Very scattered to scattered shrublands with *Acacia aneura* (mulga) or other acacias and *Triodia spp.* (spinifex) understorey. Also *Triodia spp.* hummock grasslands.
3.	Lower footslopes	10%	Very gently inclined slopes extended for up to 500m below unit 1, mantles of very abundant pebbles of mixed lithology.	Red shallow loams (522).	Hummock grasslands of *Triodia spp.* (hard spinifex) with isolated to scattered *Acacia spp.* shrubs or *Eucalyptus leucophloia* trees. Less frequently with *Triodia pungens* (soft spinifex).
4.	Stony plains	20%	Level to undulating plains and interfluves extending for up to 2km below units 1, 2 and 3; mantles of abundant to very abundant pebbles of chert, shale, dolomite and other rocks.	Red deep loamy duplex soils (506) with minor red shallow loams (522) and red shallow sandy duplex soil (406).	Hummock grasslands of *Triodia wiseana, T. spp.* (hard spinifex) with isolated to very scattered *Acacia spp.* shrubs and occasional eucalypt trees. Occasionally hummock grasslands of *Triodia pungens* (soft spinifex).
5.	Drainage floors	8%	Dendritic floors less than 100m wide with channels incised in narrow valleys in upper parts of system becoming broader (up to 250 m wide) with channels up to 50m wide further downstream.	Red loamy earths (544) with river bed soils (705) in channels.	Scattered tall shrublands/woodlands with *Acacia* and *Eucalyptus spp.* and hummock grass *Triodia spp.* understorey.

Table 8: Characteristics of the Capricorn system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Ridges, hills and upper slopes	70	Rocky summit and hills and ridges extending for many kilometres with moderately inclined to very steep upper slopes and surface mantles of abundant to very abundant pebbles, cobbles and stones, frequent exposure of bedrock; relief up to 150m.	Stony soils (203).	Hummock grasslands of *Triodia wiseana, T. brizoides* (hard spinifex) or *T. pungens* (soft spinifex) with scattered *Acacia inaquilatera* (kanji) and other Acacia spp. and *Grevillea wickhammi* (Wickham's grevillea).
2.	Lower footslopes	20	Very gently to gently inclined concave or benched lower slopes below hills, mantles of abundant pebbles and cobbles and exposures of bedrock.	Red shallow loams (522).	As for unit 1.
3.	Stony plains	5	Gently undulating to undulating plains and interfluves extending for up to 1km below hills and hill slopes, mantles of abundant pebbles and cobbles.	Red shallow sands (423) and red shallow loams (522).	Hummock grasslands of T. wiseana or T. pungens with scattered Acacia spp. shrubs.
4.	Narrow drainage floors and channels	5	Drainage floors usually less than 200m wide with channels incised in bedrock in upper parts and up to 50m wide in lower parts.	River bed soils (705).	Scattered tall shrublands or low woodlands with Acacia spp., Corymbia hamersleyana (Hamersley bloodwood), numerous other shrubs and soft spinifex.

Table 9: Characteristics of the Robe system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Low plateaux, mesas and buttes	60%	Up to 50m high above surrounding plains in lines up to 20km or more in length; level to very gently inclined crests, near vertical breakaway faces up to 10m high, moderately inclined to steep upper slopes; surface mantles of abundant to very abundant pisolitic limonite gravels and outcrops of limonite.	Stony soils (203) and shallow gravel soils (304).	Hummock grasslands of *Triodia pungens* (soft spinifex) with isolated to scattered *Acacia* and *Senna spp.* shrubs and occasional *Eucalyptus leucophloia* (snappy gum) trees.
2.	Lower slopes	20%	Very gently inclined to gently inclined slopes rarely extending more than 300m down slope, surface mantles of very abundant pisolitic limonite gravels.	Red shallow loams (522) and minor calcareous shallow loams (521).	Hummock grasslands of Triodia wiseana, T. longiceps (hard spinifex) with isolated to very scattered Acacia and Senna spp. shrubs. Occasionally hummock grasslands of Triodia pungens (soft spinifex).
3.	Gravelly plains	15%	Level to gently undulating plains extending for up to 1km, surfaces mantles of many to very abundant limonitic and other gravels.	Red loamy earths (544).	As for unit 2.
4.	Drainage floors and channels	5%	Almost level floors up to 300m wide, shallow central flow lines with little incision; also major channels up to 40m wide.	Red loamy earths (544). Channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* with very scattered to moderately close *Acacia spp.* shrubs. Also moderately close *eucalpyt* or *acacia* woodlands/tall shrublands with *T. pungens* understorey.

Table 10: Characteristics of the Laterite system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Mesa and low hills	30%	Lateritised residuals up to 2km long and 200m wide, up to 20m high; nearly level mesa tops or rounded crests, vertical breakaway faces up to 3-4m; surface mantles of very abundant laterite, ironstone and shaly gravels.	Stony soils (203) and red shallow sands (423).	Hummock grasslands of Triodia spp. (hard spinifex) with isolated shrubs. Less frequently tall shrublands of Acacia aneura (mulga) with other acacias, Senna and Eremophila spp.
2.	Mesa footslopes	15%	Very gently to gently inclined slopes extending up to 300m downslope between shallow, sub-parallel drainage lines; mantles of very abundant lateritic or ironstone pebbles.	Red shallow sands (423) or red shallow loams (522).	Very scattered to scattered tall or mid height shrublands with Acacia aneura, Senna spp., Eremophila cuneifolia (royal poverty bush) and other eremoprhia spp.
3.	Gravelly plains	35%	Level to very gently inclined plains and interfluves up to 2km in extent, separated by narrow drainage lines; mantles of many to very abundant ironstone gravels.	Shallow gravel soils (304).	Scattered mixed height shrublands dominated by Acacia aneura, other acacias, Senna, Eremophila and Ptilotus spp. Occasionally shrubby hummock grasslands Triodia spp. (hard spinifex). Also more saline sites patchy halophytic low shrublands with Maireana and Frankenia spp. and Acacia victoriae (prickly acacia).
4.	Sluggish drainage tracts	10%	Level tracts up to 500m wide and 3km long with sluggish internal drainage lines, sometimes with gilgai microrelief; variable density surface mantles of ironstone gravels.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Tussock grasslands with patchy *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail). Also patchy low shrublands with *Eremophila lachnocalyx, Acacia victoriae, Maireana, Atriplex* and *Halosarcias spp.*
5.	Drainage floors with braided creeklines	10%	Almost level floors up to 200m wide and 2km long with numerous braided flowlines with minor incision.	Deep red/brown non-cracking clays (622) with channels of river bed soils (705).	Moderately close tall shrublands/woodlands of *Acacia aneura* and other *acacias* with numerous low shrubs.

Table 11: Characteristics of the Jamindie system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Low ridges and hills	5%	Ridges and hills up to 25m high and 1.5km long, gently inclined footslopes with mantles of abundant pebbles and cobbles and some rock outcrop.	Stony soils (203).	Hummock grasslands of Triodia spp. (hard spinifex) with very scattered Acacia spp. shrubs and occasional eucalypt trees.
2.	Stony upper plains and low rises	20%	Gently undulating plains up to 3km in extent, up to 20m above lowest units; surface mantles of many to very abundant pebbles and cobbles of ironstone and other rocks.	Stony soils (203) and red shallow loams (522).	Shrubby hummock grasslands of *Triodia spp.* (hard spinifex) or scattered to moderately close tall shrublands with *Acacia xiphophylla* (snakewood), *A. aneura* (mulga) with shrub understoreys or *Triodia spp.* (hard and soft spinifex) understorey).
3.	Hardpan plains	50%	Almost level plains up to 8km in extent by 4-5km wide between shallow drainage tracts (unit 6); surface mantles of many to very abundant pebbles of ironstone and chert, subject to sheet overland flow.	Red-brown hardpan shallow loams (523).	Very scattered tall shrublands of *Acacia aneura* and other acacias with sparse *Eremophila* and *Ptilotus spp*. Occasionally *Triodia pungens* (soft spinifex) in ground layer.
4.	Groves	15%	Accurate drainage foci, up to 400m long and 20m wide but commonly mush less, on hardpan plains (unit 3), arranged with long axes at right angles to direction of sheet overland flow.	Red loamy earths (544).	Close tall shrublands/woodlands of *A. aneura* with numerous *Eremophila*, *Ptiotus* and *Sida* spp. mid and low shrubs and sparse tussock grasses. Less frequently *Triodia pungens* in ground layer.
5.	Gilgai plains	2%	Level plains less than 1km in extent associated with drainage tracts (unit 6) or as isolated areas within unit 3; gilgai microrelief.	Self-mulching cracking clays (602).	Scattered tall shrublands of *A. aneura* and other acacias and understorey of low shrubs and sparse tussock of hummock grasses.
6.	Drainage tracts	5%	Nearly level tracts associated with hardpan plains receiving more concentrated through flow and usually 300-400m wide but up to 1km channelled or unchanneled; hardpan exposed in parts.	Red-brown hardpan shallow loams (523) and minor red loamy earths (544).	Scattered tall shrublands of A. aneura and other acacias and understorey of low shrubs and sparse tussock or hummock grasses.
7.	Sandy banks	2%	Banks up to 0.5m high, mostly less than 100m long and 10 to 20m wide, on unit 3; loose hummocky surfaces.	Red deep sands (445).	Shrublands with *A. aneura* and other *acacias* with *Eremophila* and *Senna spp.* low shrubs and *Triodia spp.* (hard and soft spinifex) ground layer.
8.	Channels and banks	1%	Channels 5-50m wide, finely incised 1-2m in hardpan on broad plains, up to 5m in lower parts.	River bed soils (705).	Scattered to moderately close tall shrublands/woodlands with *A. aneura* and other acacias and tussock grasses.

Table 12: Characteristics of the River system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Sandy levees and sand sheets	15%	Narrow (generally <300m wide), ill-defined sandy levees franking units 2 and 5 and raised up to 5m (occasionally higher) above unit 3; also as broader sandy sheets moundy surfaces.	Mostly red deep sands (445) with red sandy earths (463), red loamy earths (544) river bed soils (705).	Hummock grasslands of *Triodia pungens* (soft spinifex) with very scattered to moderately close shrubs such as *Acacia trachycarpa* (miniritchie) *and A. inaequilatera* (kanji). Tussock grasslands of *Cenchrus ciliaris* (buffel grass), *Eragrostis eriopoda* (wolly butt) with very scattered to scattered acacia shrubs and trees or open eucalypt woodlands with grass understorey of *C. ciliaris*.
2.	Upper terraces	5%	Level, upper terraces marginally higher (1-2m) than unit 3, up to 500m wide, surfaces mantle absent or few to many water worn pebbles; subject to occasional flooding.	Red deep sands (445).	Hummock grasslands of *Triodia spp.* (hard spinifex) or *T. pungens* (soft spinifex) frequently with no shrubs, occasionally isolated to very scattered *Acacia spp.* shrubs and trees such as *Hakea subarea* (corkwood).
3.	Flood plains and lower terraces	50%	Level flood plains and terraces flanking single and multiple channels of the majors rivers, commonly 300-800m wide but up to 2km in lower reaches, often with moundy surfaces; subject to fairly regular flooding.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Tussock grasslands of *Cenchrus ciliaris* (buffel grass) or hummock grasslands mainly of *Triodia pungens* (soft spinifex). Also scattered to moderately close *Eucalyptus victrix* (coolabah) or acacia woodlands/tall shrbulands with prominent tussock grass understorey of *C. ciliaris*, *Chrysopogon fallax* (ribbon grass), *Eulalia aurea* (silky brown top) and others or hummock grass understory of *Triodia pungens*.
4.	Stony plains	10%	Level to very gently inclined plains up to 500m in extent with surfaces mantles of common to very abundant pebbles and water worn cobbles; some are active flood areas over old cobble beds.	Red shallow loams (522) and rede shallow sands (423).	Hummock grasslands of *Triodia spp.* (soft and hard spinifex) with very scattered to scattered acacia shrubs. Also woodlands/tall shrublands with *Eucalyptus victrix*, A*cacia spp.* and tussock and hummock grasses.
5.	Minor and major channels	20%	Channels 30-1,000m wide between sandy banks 1-10m above channel beds, bedloads of sand, gravel, pebbles and stones.	River bed soils (705).	Channels – no vegetation. Banks – close or closed fringing woodlands with Eucalyptus camaldulensis (river red gum), *E. victrix*, *Melaleuca argentea* (cadjeput), *M. glomerata*, *Sesbania formosa* (white dragon tree), *Acacia coriacea* (river jam) with understorey of sedges and grasses including *Cyprus vaginatus*, *Cenchrus ciliaris* and *Triodia pungens*.

Table 13: Characteristics of the Newman system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Plateaux, ridges, mountains and hills	70%	Mountain tracts, plateaux and strike ridges, relief up to 400m; level or rounded plateaux summits and mountain crests, ridges and indented escarpments with vertical upper cliff faces and moderately inclined to very steep upper scree slopes; surface mantles of abundant to very abundant pebbles, cobbles and stones of ironstone, jaspilite, chert and other rocks. Also outcrop of parent rock.	Stony soils (203), red shallow loams (522) and some red shallow sands (423).	Hummock grasslands of *Triodia wiseana, T. brizoides, T. plurinervate* with very scattered to scattered shrubs and trees including *Acacia* and *Senna spp.*, *Grevillea wickhamii* (Wickham's grevillea), *Eucalpytus leucophloia* (snappy gum) and other eucalypts. Occasionally hummock grass is *Triodia biflora* (soft spinifex).
2.	Lower slopes	20%	Gently inclined concave slopes mostly less than 400m in extent with mantles of very abundant pebbles and cobbles of ironstone and other rocks.	Stony soils (203) on upper margines with red loamy earths (544) on lower margins.	Similar to Unit 1.
3.	Stony plains	5%	Gently undulating lower plains and interfluves up to 500m in extent with mantles of abundant to very abundant pebbles of ironstone.	Stony soils (203), red shallow loams (522) with some red loamy earths (544).	Hummock grasslands of *Triodia wiseana, T. spp* (hard spinifex) with isolated to very scattered shrubs of *Acacia* and *Senna spp.* and occasional eucalypt trees. Occasionally hummock grasslands of *Triodia pungens* (soft spinifex).
4.	Narrow drainage floors and channels	5%	Almost level floors up to 400m wide but usually much less in valleys, mantles of abundant pebbles of ironstone and other rocks; channels up to 200m wide with cobble bedloads.	Red shallow loams (522), red loamy earths (544). Channels with river bed soils.	Smaller floors support hummock grasslands of *Triodia pungens* with very scattered shrubs. Larger floors and channels support tall shrublands/woodlands of *Acacia spp.* and *Eucalyptus victrix* (coolabah) with tussock grass or hummock grass understoreys.

Table 14: Characteristics of the Elimunna system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Hills and low rises	10%	Low (up to 15m) isolated hills and rounded rises with surface mantles of abundant or very abundant pebbles and cobbles of basalt and other rocks.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) or very scattered shrublands of *Acacia* and *Senna spp.*
2.	Stony plains	45%	Level to gently undulating plains extending up to 4km, mantles of abundant pebbles of basalt, quartz and ironstone.	Red/brown non-cracking clays (622).	Very scattered to scattered mixed height shrublands with *Acacia aneura* (mulga) other acacias, *Senna spp.* (cassias) and *Eremorphilia spp.* Occasionally with patchy *Triodia spp.* (hard spinifex) understorey.
3.	Gilgai plains	26%	Level plains with gilgai microrelief, with or without surface mantles; up to 1km in extent or as a mosaic of patches 10-50m in size occurring on unit 2.	Self-mulching cracking clays (602) and red deep loamy duplex soils (506).	Patchy tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (nverfail), *Astrebla pectinata* (barley Mitchell grass) with isolated shrubs mainly *Eremorphila* and *Senna spp.*
4.	Hardpan plains	6%	Level plains subject to sheet flow, mantles of many to abundant ironstone pebbles.	Red loamy earths (544).	Very scattered tall shrublands of *A. aneura* and other acacias.
5.	Groves	1%	Discrete drainage foci (up to 50m long by 5-15m wide) arranged more or less at right angles to sheet flow on stony plains and hardpan plains (units 2 and 4).	Red loamy earths (544).	Moderately close to close tall shrublands of *A. aneura* with numerous other shrubs and patchy perennial grass.
6.	Drainage floors	12%	Level tracts within units 2 and 3 with variable surface mantles and patches of gilgai microrelief, with central channels or sluggish internal drainage lines.	Self-mulching cracking clays (602).	Tussock grasslands with *Astrebla* and *Eragrostis spp.* or very scattered to moderately close tall shrublands of *Acacia spp.* with various low shrubs and patchy tussock and/or hummock grasses.

Table 15: Characteristics of the Spearhole system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Low rises	15%	Gently rounded crest with very gently inclined slopes, extending up to 1km and mostly up to 15m relief above general level of surrounding plains, surface mantles of abundant ironstone gravel.	Red loamy earths (544) and red-brown hardpan shallow loams (523).	Very scattered to scattered tall shrublands with Acacia aneura (mulga), A. pruinocarpa (gidgee), and other acacias with sparse low shrubs Eremophila and Ptilotus spp. with or without Triodia spp. (hard spinifex) ground layer.
2.	Gravelly hardpan plains	55%	Level or gently undulating plains or intergrove areas up to 6km or more in extent with surface mantles of abundant ironstone gravel subject to sheet flow.	Red-brown hardpan shallow loams (523), red loamy earths (544) and some red sandy earths (463).	Very scattered to moderately close tall shrublands of Acacia aneura, A. catenulate with Eremorphila and Ptilotus spp. low shrubs with or without a prominent ground layer of Triodia spp. (hard spinifex). Also hummock grasslands of Triodia spp. (hard spinifex) with few shrubs.
3.	Groves	15%	Groves or arcuate bands up to 1.5km long by 100m wide (though commonly much smaller) arranged on hardpan plains (unit 2) with long axes at right angles to direction of sheet flow.	Red loamy earths (544) and red-brown hardpan loams (523).	Close woodlands/tall shrublands with Acacia aneura, A. catenulate and other acacias with numerous low shrubs of Eremophila, Ptilotus, Sida spp. and occasionally perennial grasses.
4.	Dissected slopes	10%	Adjacent to hardpan plains (unit 2) and extending up to 1km downslope to drainage lines or as stripped margins to other land systems, often intensely dissected up to 20m to give a series of spur slopes and interfluves with gently inclined slopes.	Red shallow loams (522) and red-brown hardpan shallow loams (523).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with very scattered *Acacia spp.* shrubs and occasional trees such as *Eucalyptus socialis*, *Corymbia hamersleyana* (Hamersley bloodwood).
5.	Drainage zones and channels	5%	Drainage zones 10-40m wide in upper parts becoming wider downslope, channels incised 1-2m in hardpan or centrally positioned in shallow valleys incised up to 20m with flanking slopes of unit 4.	Red loamy earths (544) or red sandy earths (463). Channels with river bed soils (705).	Scattered to moderately close woodlands or tall shrublands with eucalypts and acacias, low shrubs and prominent ground storey of *Triodia spp.* (hard spinifex) or tussock grasses.

Table 16: Characteristics of the Granitic system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Hills, ridges, domes, and upper slopes	40%	Hill crests and ridge summits with mantles of abundant pebbles, cobbles and stones and outcrop of granitic rocks; tor heaps and bare rounded dome surfaces of exposed rock; moderately inclined to steep upper slope with mantles of abundant pebbles, cobbles and stones; relief up to 80m.	Stony soils (203), red shallow sands (423) and bare rock.	Hummock grasslands predominately *Triodia spp.* (hard spinifex), less frequently *Triodia pungens* (soft spinifex) with isolated or very scattered shrubs such as *Acacia inaequilatera* (kanji), *A. trachycarpa* and other acacias.
2.	Lower slopes	40%	Very gently to gently inclined rocky slopes with mantles of abundant pebbles, cobbles and stones and outcrops of granitic rocks, extending for up to 2km below unit 1.	Red shallows sands (423).	Hummock grasslands as for unit 1. Occasionally low or mid height shrublands of *Acacia* and *Eremophilia spp.* with prominent ground layer of *Triodia spp.*
3.	Stony plains	15%	Gently undulating stony or gritty surfaced plains extending for up to 1km below units 1 and 2, surface mantles vary from very few to abundant pebbles of granitic material quartz.	Red shallow sands (423) and red loamy earths (544).	Hummock grassland of *Triodia pungens* (soft spinifex) or *Triodia wiseana* (hard spinifex) with very scattered acacia shrubs. Less frequently acacia shrublands with soft spinifex understorey.
4.	Narrow drainage floors and channels	5%	Almost level floors <50m wide in narrow valleys in upper parts becoming up to 300m wide further downstream; channels up to 100m wide with banks to 4m.	Red shallow sands (423) and shallow river bed soils (705) in channels.	Small floors have hummock grasslands of soft or hard spinifex with scattered shrubs. Larger floors with channels support moderately close to close tall shrublands/woodlands with *Acacia, Eucalyptus* and *Melaleuca spp.* with hummock or tussock grasses.
5.	Drainage foci	<1%	Isolated foci up to 200m in extent at base of, and receiving run-on from, bare domes or hills (unit 1).	Red shallow sands (423).	Close tall shrublands of *Acacia tumida* (pindan wattle) or other acacias with variable mid and low shrubs and tussock grasses.

Table 17: Characteristics of the Turee system (adapted from van Vreeswyk *et al.* 2004).

Unit	Landform element	% of landform element within land system	Description	Soil	Vegetation
1.	Hardpan plains	10%	Level plains up to 1.5km in extent, mantles of very few to common pebbles; usually located on outer margins of system, subject to sheet water flow.	Red-brown hardpan shallow loams (523) or red shallow loams (522).	Very scattered tall or low shrublands with *Acacia aneura* (mulga) and *Eremophila* and *Senna spp.*
2.	Groves and drainage foci	1%	Up to 200m in extent but commonly smaller or hardpan plains and stony plains (unit 1 and unit 3), receiving run-on from adjacent surfaces.	Red loamy earths (544) or deep red/brown non-cracking clays (622).	Close tall shrublands of *A. aneura* with *Eremophila* and *Senna spp.* undershrubs and perennial grasses such as *Chrysopogon fallax* (ribbon grass).
3.	Stony plains	25%	Level plains with mantles of abundant to very abundant pebbles of ironstone and other rocks; up to 5km in extent or as an irregular mosaic 20-500m in extent with similarly sized or larger areas of slightly lower gilgai plains.	Red shallow loams (522) and red-brown hardpan shallow loams (523).	Very scattered to scattered tall or low shrublands with *Acacia xiphophylla* (snakewood). *A. aneura*, *Senna artemisioides* subsp. *oligophylla* (blood bush) and *eremophila spp.*
4.	Gilgai plains	45%	Level plains with gilgai microrelief and mantles of very few to abundant pebbles of ironstone and other rocks; up to 2km in extent or as an irregular mosaic 20-500m in extent with slightly higher non-gilgaied stony plains (unit 3 and 5).	Self-mulching cracking clays (602) and red deep loamy duplex soils (506).	Tussock grasslands or patchy grassy shrublands with *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail) and isolated to very scattered shrubs including *Acacia farnesiana* (mimosa bush), *A. victoriae* (prickly acacia), *Senna* and *Eremophila spp.* Sometimes degraded to annual herbfield.
5.	Saline stony plains	10%	Level plains with mantles of variable abundance grit and pebbles of ironstone; up to 2km in extent, subject to sheet flow.	Red deep loamy duplex soils (506).	Very scattered to scattered low shrublands with *Atriplex bunburyana* (silver saltbush), *Maireana spp.* (bluebush), *Senna Eremophila* and *Acacia spp.*
6.	Channelled drainage tracts	10%	Through going tracts up to 1km wide but commonly much less, 1-2m below surrounding plains; short pebble strewn slopes marginal to adjacent plains, pebble mantles of variable abundance; anastomosing channels up to 50m wide in central parts.	Red deep loamy duplex soils (506). Channels with riverbed soils (705).	Small tracts support grassy scattered shrublands with *Acacia farnesiana*, Er*agrostis setifolia* and *Eriachne berthamii* (swamp grass). Larger tracts with channels support tall shrublands or low woodlands with *Acacia coriacea* (river jam), other acacias, *Eucalyptus victrix* (coolabah) with patchy tussock grasses including *Cenchrus ciliaris* (buffel grass).

Table 18: Summary of landform units within the Survey area based on land system mapping.

Landform unit	Associated land systems	Landforms	Area within Pilbara region (ha)	Percentage of Pilbara	Area in the Survey Area (ha)	Proportion within Survey Area (%)
Upper erosional surfaces	Rocklea, Mckay, Capricorn, Robe, Laterite, Jamindie	Hills, ridges, plateaux, mesas, breakaways, buttes, mountains and hills.	3,376,593	18.5%	8,554	9
Lower slopes	Rocklea, McKay, Capricorn, Robe, Laterite, Newman, Spearhole, Granitic	Lower slopes, lower footslopes, mesa footslopes and dissected slopes.	980,131	5.4%	5,703	6
Stony plains	Rocklea, Bonney, Wona, McKay, Capricorn, Robe, Laterite, Jamindie, River, Newman, Elimunna, Spearhole, Granitic, Turee	Stony plains and interfluves, stony plains and slopes, gravelly plains, stony upper plains and rises, hardpan plains, gravelly hardpan plains, saline stony plains.	867,493	4.8%	61,568	64
Floodplains and terraces	River	Sandy levees and sand sheets, upper and lower terraces, floodplains.	292,495	1.6%	1,300	1
Drainage lines and floors	Rocklea, Bonney, Wona, McKay, Capricorn, Robe, Laterite, Jamindie, River, Newman, Elimunna, Spearhole, Granitic, Turee	Upper drainage lines, drainage lines, drainage floors and channels, minor and major channels, narrow drainage floors and channels, sluggish drainage tracts, channelled drainage tracts, drainage foci. Groves, groves and drainage foci.	560,283	3.1%	4,120	4
Hills and rises	Bonney, Wona, Elimunna, Spearhole	Hills, low rises, low basalt hills, low rises.	59,771	0.3%	8,097	8
Gilgai plains	Rocklea, Bonney, Wona, Jamindie, Elimunna, Turee	Gilgai plains, stony gilgai plains, Stony gilgai upland plains.	195,845	1.1%	7,532	8

2.2 Atlas of Australian Soils

The Atlas of Australian Soils (Northcote *et al*, 1960-1968) was compiled by CSIRO in the 1960s to provide a consistent national description of Australia's soils. It comprises a series of ten maps and associated explanatory notes. The maps are published at a scale of 1:2,000,000, but the original compilation was at scales ranging from 1:250,000 to 1:500,000. Mapped units within the Atlas are soil landscapes usually comprising several soil types. The explanatory notes include descriptions of soil landscapes and component soils.

An assessment of the Atlas mapping over the Survey area indicates the presence of five soil landscapes:

1. Oa11 (75%);
2. Oc70 (12%);
3. Gf1 (10%);
4. Fb8 (2%); and
5. Mz25 (1%).

The distribution of the soil landscapes within the Survey area is illustrated in Figure 3 and descriptions are provided in Table 19.

The Oa11 soil landscape is present across 75% of the Survey area. This soil landscape is comprised of dissected stony pediments and hills that occur at the foot of the steep ranges of unit Gf1. Major soils are hard alkaline soils. Two Australian Soil Classification (ASC) soil units have been described within this soil landscape, Chromosol and Vertosol. Chromosols are soils that contain a clear texture contrast and are not sodic and not strongly acidic. Vertosols are clay soils that exhibit shrink-swell properties, such soils are typically associated with the presence of gilgai.

The Oc70 unit is present across 12% of the Survey area. Similar to Oa11, Oc70 is comprised of dissected pediments and low stony hills. These landforms are associated with cherts, jaspilites and iron formations. The main soils of this soil landscape are alkaline red soils which are classified as the ASC order Sodosol. The Kandosol soil order is also present within this unit. Sodosols are characterised by a clear texture contrast, with the subsoil typically exhibiting high levels of sodicity. Kandosols are soils that do not possess a texture contrast, and which have massively or weakly structured soil profiles.

The Gf1 soil landscape covers 10% of the Survey area and is composed of steep ranges of banded iron formations with narrow valley plains. The soils of Gf1 are typically stony brown loams, there are considerable areas of bare rock where no soil is present. The major ASC orders present are Tenosol and Sodosol. Tenosols are soils with only weaky developed pedological structure.

Fb8 is associated with 2% of the Survey area. This soil landscape is described of consisting of plains of deep earthy loams. The single ASC order attributed to Fb8 is Kandosol.

Mz25 is present exclusively in the most southwestern reaches of the Survey area, covering a total of 1% of the footprint. Mz25 consists of plains associated with the Fortescue valley. Major soils are red earths, attributed to the Kandosol ASC order.

Table 19: Soil landscapes of the Survey area.

Soil landscape	% of Survey Area	Australian Soil Classification	Description
Oa11	75	Chromosol Vertosol	Dissected stony pediments and hills occurring at the foot of neighbouring BIF ranges. Major ASC type of this landscape is Chromosol.
Oc70	12	Sodosol Kandosol	Dissected pediments and low stony hills. Alkaline stony Sodosols dominate the landscape.
Gf1	10	Tenosol Sodosol	Steep ranges of BIF with narrow valley plains. Stony brown loams are the major soil of this landscape, classified as Tenosols.
Fb8	2	Kandosol	Plains consisting of deep earthy loams. Major ASC type of this landscape is Kandosol.
Mz25	1	Kandosol	Plains associated with the Fortescue valley. Major ASC type is Kandosol.

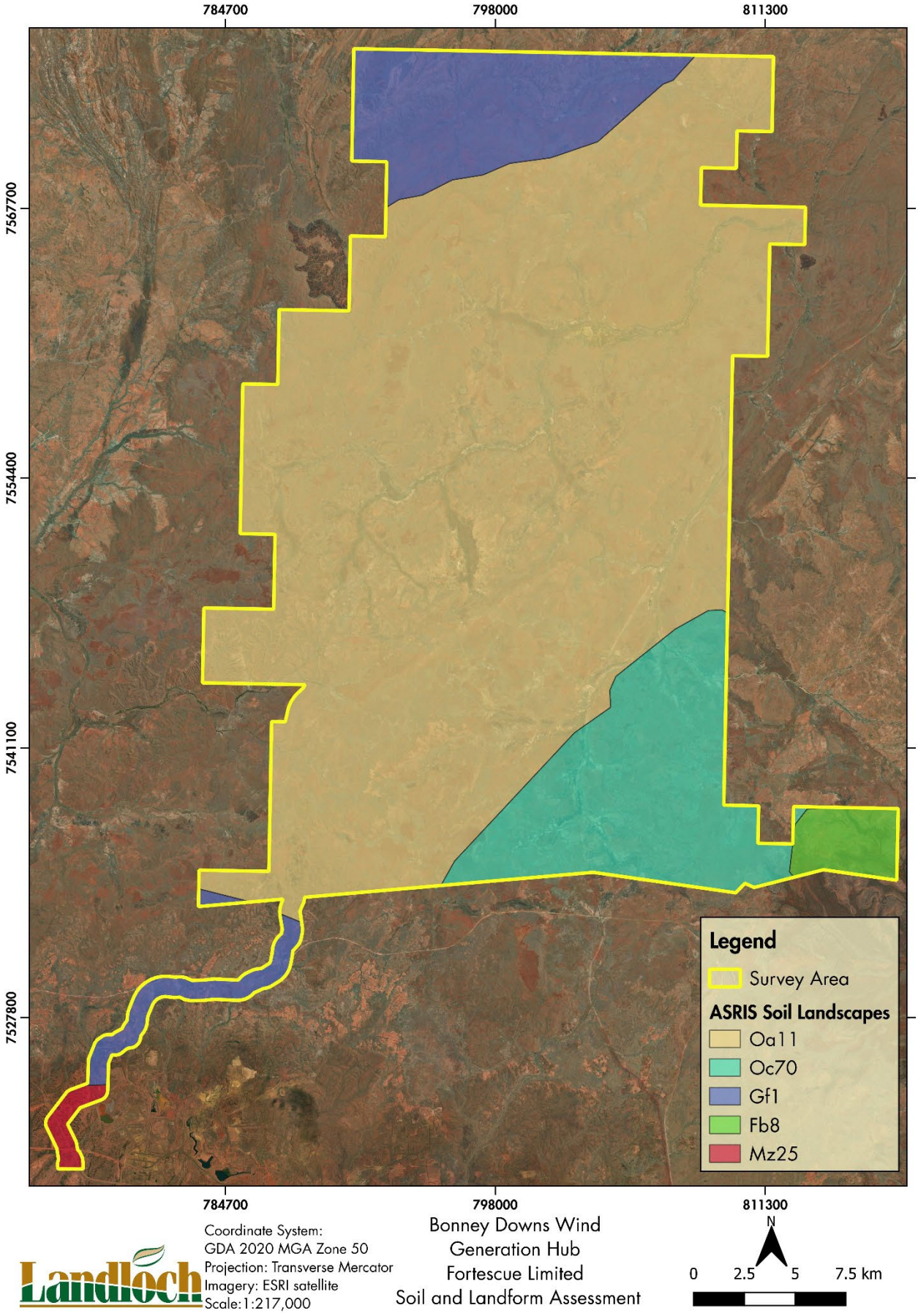

Figure 3: Distribution of soil landscapes within the Survey area.

2.3 Nullagine Iron Ore Project Soils Report

Landloch completed an assessment of baseline soils and landform data for the Nullagine Iron Ore Project (Landloch 2024a). The area assessed is approximately 4,300ha in size, an estimated 4.4% of the Survey area. As part of the report, all available site-specific data was reviewed, including:

- Preliminary Investigation of Soil Characteristics of Waste Dump Area (Land Assessment Pty Ltd 2015);
- Land unit shapefiles (Astron 2024);
- BC Iron Limited, Nullagine Iron Ore Joint Venture, Soil and Mine Waste Characterisation for Warrigal North and Bonnie East (Outback Ecology 2013); and
- Technical Memorandum: Nullagine Topsoil Characterisation Assessment (Landloch 2024b).

Data concerning the Nullagine Iron Ore Project's *in situ* soils was limited to the results of the characterisation work completed by Outback Ecology (2013) and land systems mapping. Soils were highly variable across the area, with stony soils and shallow gravelly soils present in the upper landscape, red shallow sands, loams, and duplex soils present in the upper to lower slopes, and red sandy earths, loamy earths, calcareous shallow loams and cracking and non-cracking clays present on the plains and within drainage lines.

Links between landform type and soil types from the land systems mapping were used to supplement relationships between the *in situ* soils and landscape associations developed by Outback Ecology. A limited number of *in situ* soil sites were investigated by Outback Ecology (16 sites in total), necessitating the need for extrapolation. Soil characteristics were consolidated to determine broad soil attributes present across the landforms of the Nullagine Iron Ore Project.

Following the consolidation of landform and soils data, the soil-landscape associations first developed by Outback Ecology (2013) were revised. Mapping of the revised soil–landscape incorporated both the land unit mapping by Astron (2024) and the land system mapping of van Vreeswyk et al. (2004). The soil-landscape associations are summarised in Table 20 and illustrated in Figure 4.

Table 20: Revised soil-landscape associations for the Nullagine Iron Ore Project area (Landloch 2024).

Soil-landscape association	Associated soil type and properties	% of Project area
Mesas, ridges and upper slopes	**Shallow rocky soils:** Soils with a high coarse fragment abundance on the surface and within the profile. Typically sand to loam in texture with little to no soil structure. Not prone to hardsetting but can be partly dispersive. Due to their coarse nature, these soils typically drain rapidly. They can be circum-neutral to strongly acidic, are typically non-saline and non-sodic, and have a low availability of plant nutrients.	10
Low hills and lower slopes	**Shallow sandy loams:** Soils with moderate to high coarse fragment abundance. Typically sand to loam texture but can grade to clay at a shallow depth in lower landscape positions, forming a duplex profile. Prone to hardsetting and partly dispersive. Drainage is moderate to moderately rapid. Typically, circum-neutral pH, non-saline and non-sodic, with a low to moderate availability of plant nutrients.	65
Alluvial plains	**Loamy earths:** Soils with significant variability in their coarse fragment abundance and texture. Due to their depositional nature, the loamy earths can vary from coarse sand to clay in texture. Typically hardsetting, these soils have a moderate drainage and can have rudimentary soil structure. Circum-neutral pH, non-saline, and non-sodic with a low to moderate availability of plant nutrients.	8
Gilgai plains	**Shrink/swell clays:** Soils with a high abundance of clay throughout the soil profile, with shrink-swell properties common. These clays are prone to swelling when wet and shrinking when dry, resulting in the development of gilgai micro-relief. Characteristics of these soils will vary, but they can be alkaline in pH and saline. Typically have a moderate availability of plant nutrients.	5
Upper drainage lines	**Drainage soils:** Soils developed through deposition of alluvium from surface water flows, typically with higher volumes of water. Sandy soils with a moderate to high coarse fragment abundance. Typically alkaline, with variable salinity, and with a low to moderate availability of plant nutrients.	4
Drainage floors	**Alluvial soils:** Soils developed through deposition of alluvium from surface water flows. Generally contains a higher proportion of silts and clays compared to the drainage soils. Can be saline and prone to hardsetting. Typically alkaline, with a low to moderate availability of nutrients.	8

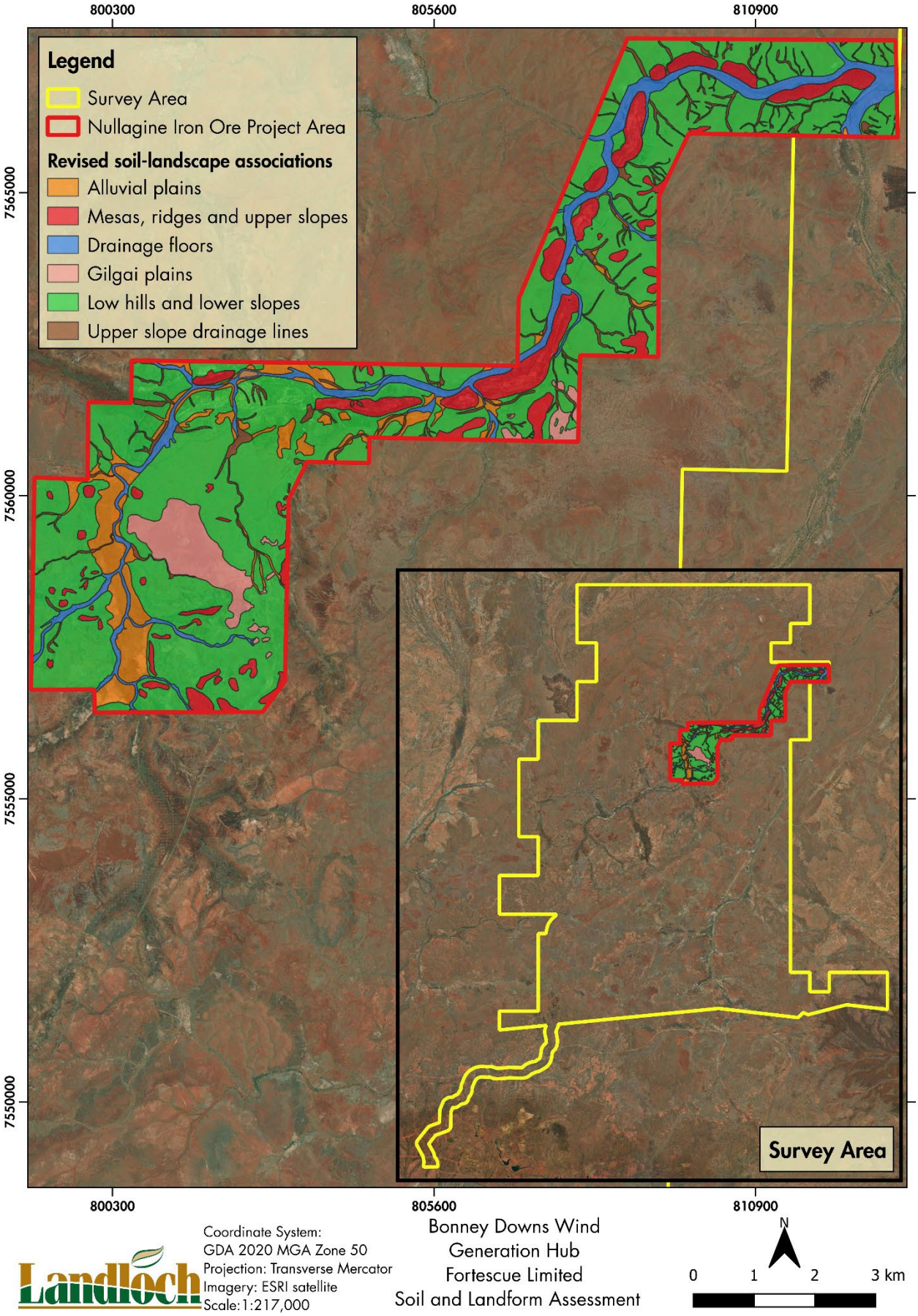

Figure 4: Revised soil-landscape association mapping (Landloch 2024).

2.4 Topography and Relief

Topography has a strong influence on the development of soils. Eroded material from hills and ridges is transported down the slope and results in the development of varying soil profiles. Drainage lines transport this material into depositional plains.

Contour data for the Survey area has been provided by Fortescue. This was converted into a Digital Elevation Model (DEM). The topography of the Survey area is varied with a maximum relief of approximately 160m. The Survey area is dominated by hills, plateaux and ridges of varying elevation. Drainage lines lead to the lower elevation landforms of the area such as the stony plains. The major drainage tracts are associated with the north-west and north-eastern reaches of the Survey area. The ridges and plateaux of the south-western corner of the Survey area are associated with the highest elevation at ~570m above sea level. The elevation across the Survey area is illustrated in Figure 5.

A slope analysis conducted over the Survey area (Figure 6) found that the majority of the Survey area is comprised of surfaces with gradients between 0-5°. Isolated areas with gradients of 10-20° occur across the Survey area, typically associated with drainage lines or hills and ridges. There are a few locations with gradients >20°, with the majority occurring in the north-western section, associated with a steep ridgeline.

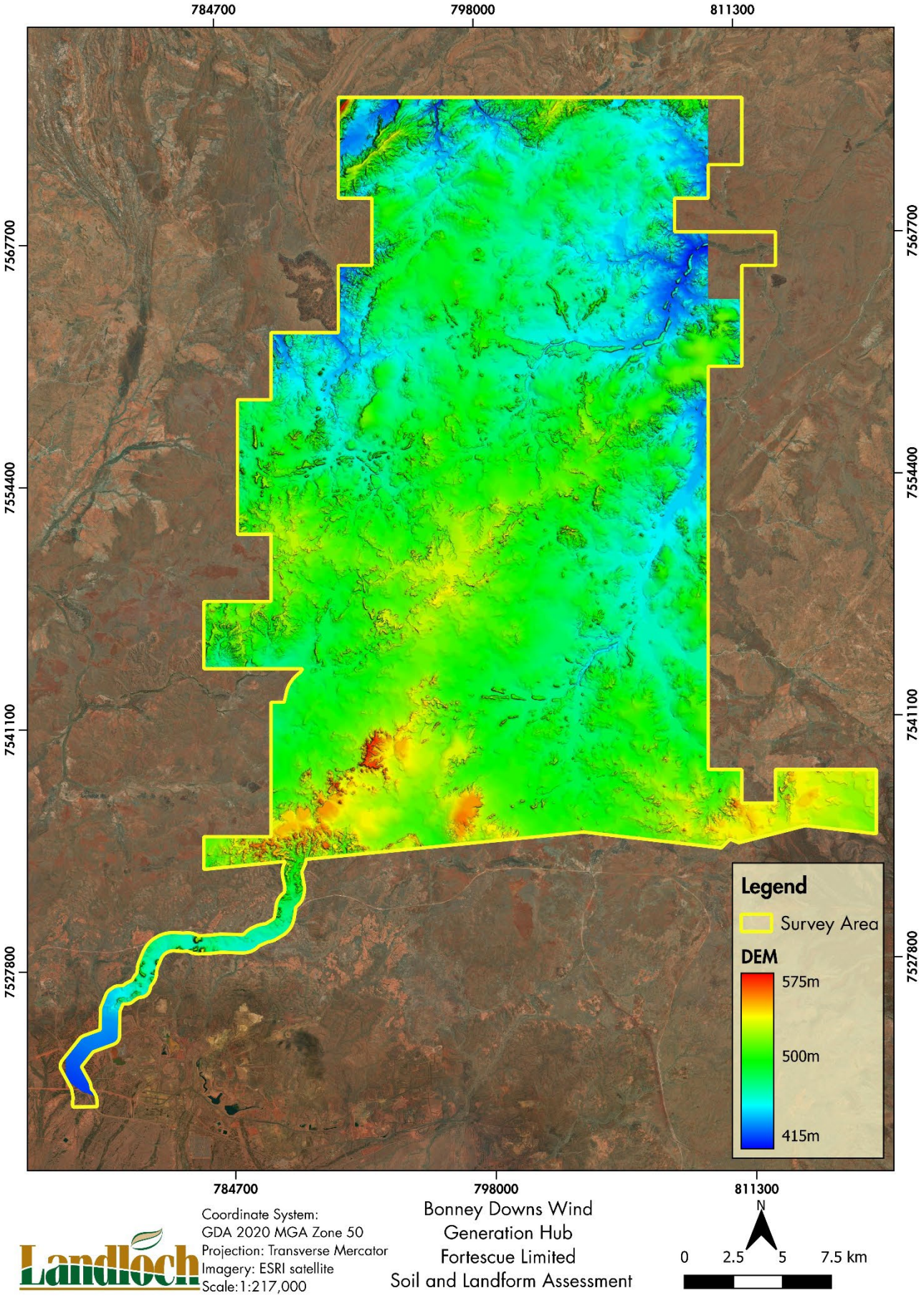

Figure 5: Digital elevation model of the Survey area.

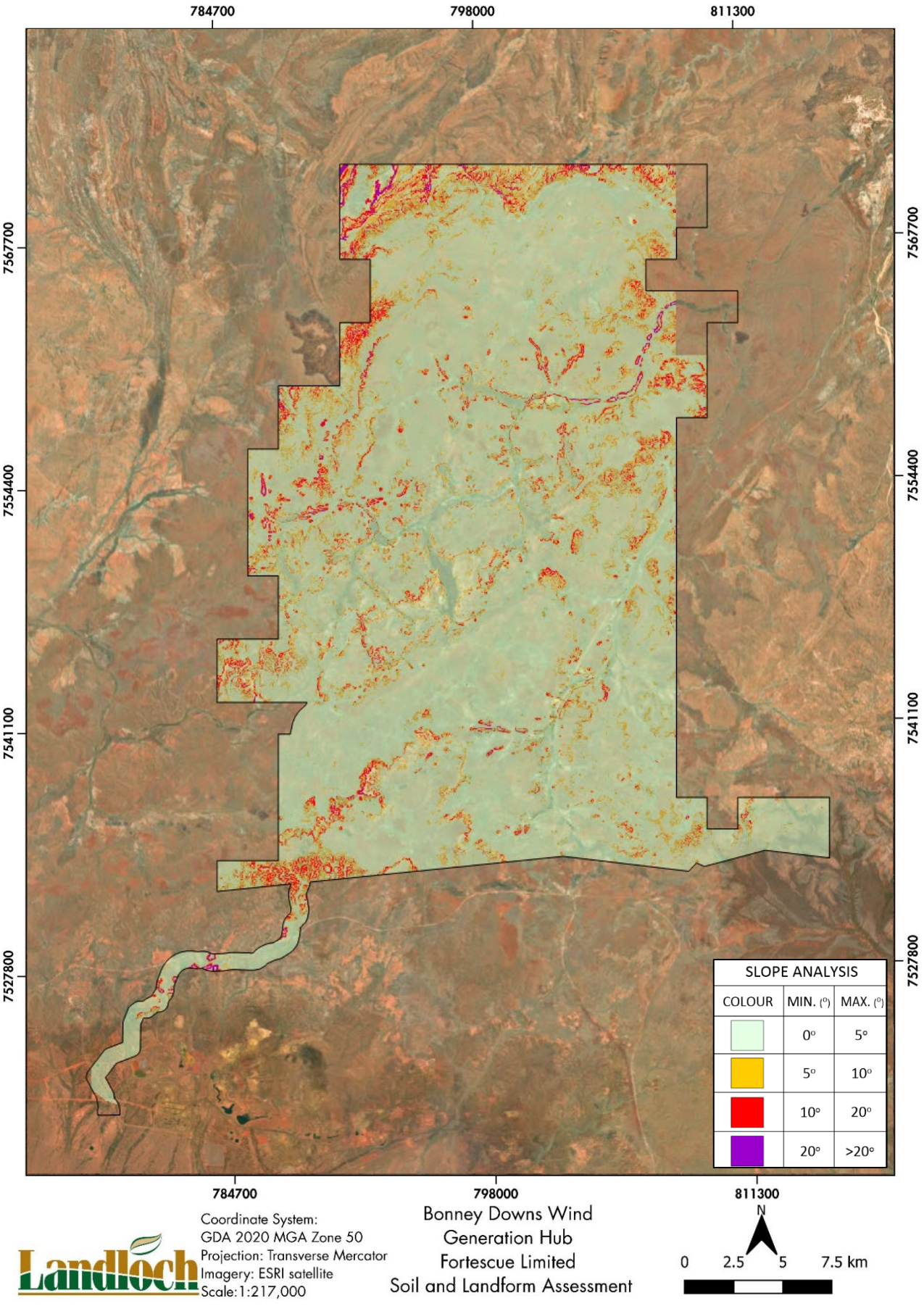

Figure 6: DEM slope analysis.

2.5 Acid Sulfate Soils

Acid sulfate soils (ASS) are soils or sediments containing iron sulfides. These iron sulfides form naturally in the soil under waterlogged conditions. When exposed to air by draining, lowering of the water table, or excavation, the oxidation of the sulfides creates sulfuric acid which can have a wide range of deleterious effects.

The term ASS includes both sulfate materials (i.e. materials that, when oxidised, will produce acid) and sulfuric materials (i.e. materials that have undergone some degree of oxidation), referred to by the following terms:

- Potential Acid Sulfate Soils (PASS) are soils or sediments that contain iron sulfides and/or other sulfidic minerals that have not been oxidised. The field pH of these materials in their undisturbed state is more than pH 4 and is commonly neutral to alkaline. These materials are fully saturated; the waterlogged layer may be peat, clay, loam, silt or sand, and is usually dark grey and soft, but may also be dark brown, pale grey to white.
- Actual Acid Sulfate Soils (AASS) are soils or sediments that contain iron sulfides and/or other sulfidic minerals that have undergone some oxidation. This results in low pH (i.e. pH <4) and often a yellow and/or red mottling (jarosite/iron oxide) in the soil profile. AASS also commonly contain residual un-oxidised sulfide minerals (i.e. potential acidity) as well as existing acidity.

The first step is to review ASS risk maps to determine if the proposed works are in an area where there is a known ASS risk. If risks are identified, the next step is to complete a preliminary desktop assessment and site inspection.

2.6 Vegetation Communities

Ecologia Environment (Ecologia) completed a detail flora and vegetation assessment of the Survey area (Ecologia 2025a). A total of 17 vegetation types were classified with vegetation typically being in excellent condition. Thirteen of the seventeen vegetation types were assessed to be significant. One vegetation type (VfAl) is consistent with a Priority 1 vegetation community, with no other observed communities corresponding to any state or federal listed Threatened Ecological Community.

A summary of the 17 vegetation types is provided in Table 21, with distribution within the Survey area shown in Figure 7. Included in the vegetation type summaries were simple landform and soil descriptions.

The most prominent vegetation type is a mosaic of AlCpTe1, AlCpTe2 and AiSgTb which covers approximately 59% of the Survey area. This mosaic is associated with the Stony plains, Hills and rises and Upper erosion surfaces landform units. The landform descriptions indicate the presence of all landform units except for Groves.

Table 21: Summary of vegetation units including associated landform units.

Veg. Unit	Vegetation type	Landform description	Associated landform unit	% of Survey area
AaCpTw	*Acacia aptaneura, Acacia tetragonophylla* tall open shrubland; *Corchorus parviflorus* low open shrubland; *Triodia wiseana*, *Enneapogon polyphyllus, Aristida contorta* low open tussock grassland.	Gravelly plains and undulating plains with reddish-brown clay-loam soils.	Stony plains	0.3
AaEp	*Acacia aptaneura, Acacia pruinocarpa* tall open shrubland; *Enneapogon polyphyllus, ±Triodia brizoides, ±Triodia longiceps* low open tussock/hummock grassland.	Gravelly plains and undulating plains with reddish-brown clay-loam soils.	Stony plains/Gilgai plains	1.1
AaTe	*Acacia aptaneura, Acacia pruinocarpa, Acacia bivenosa* tall openshrubland; *Triodia epactia* low open hummock grassland.	Primarily stony plains with red-brown clay-loam soils.	Stony plains/Gilgai plains	0.5
AaTs	*Acacia ancistrocarpa, Acacia aptaneura* tall open shrubland; Triodia scintillans low hummock grassland.	Plains and undulating plains	Gilgai plains	0.6
AcTe	*Acacia cyperophylla* var. *omearana* (P1), *Acacia tumida* var. *pilbarensis* tall sparse shrubland; *Triodia epactia*, *Triodia longiceps* mid sparse hummock grassland.	Rocky creeks and minor gullies	Drainage lines and floors	0.2
AeTe	*Acacia eriopoda* tall sparse shrubland; *Triodia epactia, Triodia longiceps* low hummock grassland.	Plains and undulating plains	Hills and rises	1.2
AhCspYTe	*Atalaya hemiglauca* tall sparse shrubland; *Corchorus sp. Yarrie* (J. Bull & D. Roberts CAL 01.05) (P1) mid open shrubland; *Triodia epactia* low sparse hummock grassland.	Plains and undulating plains	Hills and rises	<0.1
AiCpTe1	*Acacia inaequilatera* tall sparse shrubland; ±*Corchorus parviflorus* low sparse shrubland; *Triodia epactia, ±Triodia brizoides* low hummock grassland.	Low stony hills and undulating plains. Mostly ironstone and basalt with some quartz and calcrete. Reddish brown clay-loam soils.	Upper erosional surfaces/Hills and rises/Stony plains	58.9
AiCpTe2	*Acacia inaequilatera* tall sparse shrubland; *Corchorus parviflorus* low sparse shrubland; *Triodia epactia* low hummock grassland.	Primarily associated with minor drainage lines intersecting low stony hills and undulating plains. Reddish brown clay-loam soils.		

Veg. Unit	Vegetation type	Landform description	Associated landform unit	% of Survey area
AiSgTb	*Acacia inaequilatera, Hakea lorea* subsp. *lorea* tall open shrubland; *Senna glutinosa* mid open shrubland; *Triodia brizoides, Triodia epactia, Cymbopogon ambiguus* low hummock/tussock grassland.	Primarily associated with rocky ridges and outcrops. Reddish brown clay-loam soils.		
AmTe	*Acacia monticola* tall closed shrubland; *Triodia epactia* low open hummock grassland.	Drainage lines and floodplains	Hills and rises/Lower slopes/Drainage lines and floors/Floodplains and terraces	0.1
AoTe	*Acacia orthocarpa, Acacia maitlandii* tall open shrubland; *Triodia epactia* low open hummock grassland.	Rocky hills and outcrops with sandy clay loam soils.	Upper erosional surfaces	0.1
EcAcCs	*Eucalyptus camaldulensis* subsp. *refulgens*, ±*Melaleuca argentea* mid open woodland; *Acacia coriacea subsp. pendens, Acacia trachycarpa* tall open shrubland; * *Cenchrus setiger, Triodia longiceps* low tussock/hummock grassland.	Sandy creek	Drainage lines and floors	0.1
ElAbTl	*Eucalyptus leucophloia* subsp. *leucophloia, ±Corymbia hamersleyana* low open woodland; *Acacia bivenosa* mid sparse shrubland; *Triodia longiceps, Triodia wiseana*, ±*Triodia brizoides* low hummock grassland.	Low stony hills, plains, and undulating plains sometimes with dissecting drainage lines. Often with quartz and calcrete. Reddish brown clay-loam.	Drainage lines and floors/Stony plains/Hills and rises	16.7
ElGwTe	*Eucalyptus leucophloia* subsp. *leucophloia*, ±*Corymbia hamersleyana* low open woodland; *Grevillea wickhamii* mid sparse shrubland; *Triodia epactia, Eriachne lanata, Eriachne mucronata* low hummock/tussock grassland.	Low rocky hills and ridges with red-brown clay-loam soil	Upper erosional surfaces/Hills and rises/Lower slopes	7.5
EvAcCc	*Eucalyptus victrix, ±Eucalyptus camaldulensis* subsp. *refulgens* mid open woodland; *Acacia coriacea subsp. pendens, Acacia pyrifolia* var. *pyrifolia, Atalaya hemiglauca* tall open shrubland; * *Cenchrus ciliaris, Triodia longiceps, Triodia epactia* low tussock/hummock grassland.	Minor and major creeks and minor gullies.	Drainage lines and floors	4.7
VfAl	* *Vachellia farnesiana* mid sparse shrubland; *Aristida latifolia, Cynodon convergens, Eriachne mucronata* low tussock grassland.	Low hills and plains with clay soils, often stony.	Gilgai plains/Hills and slopes	6.8
Cleared	N/A	N/A	N/A	1.0

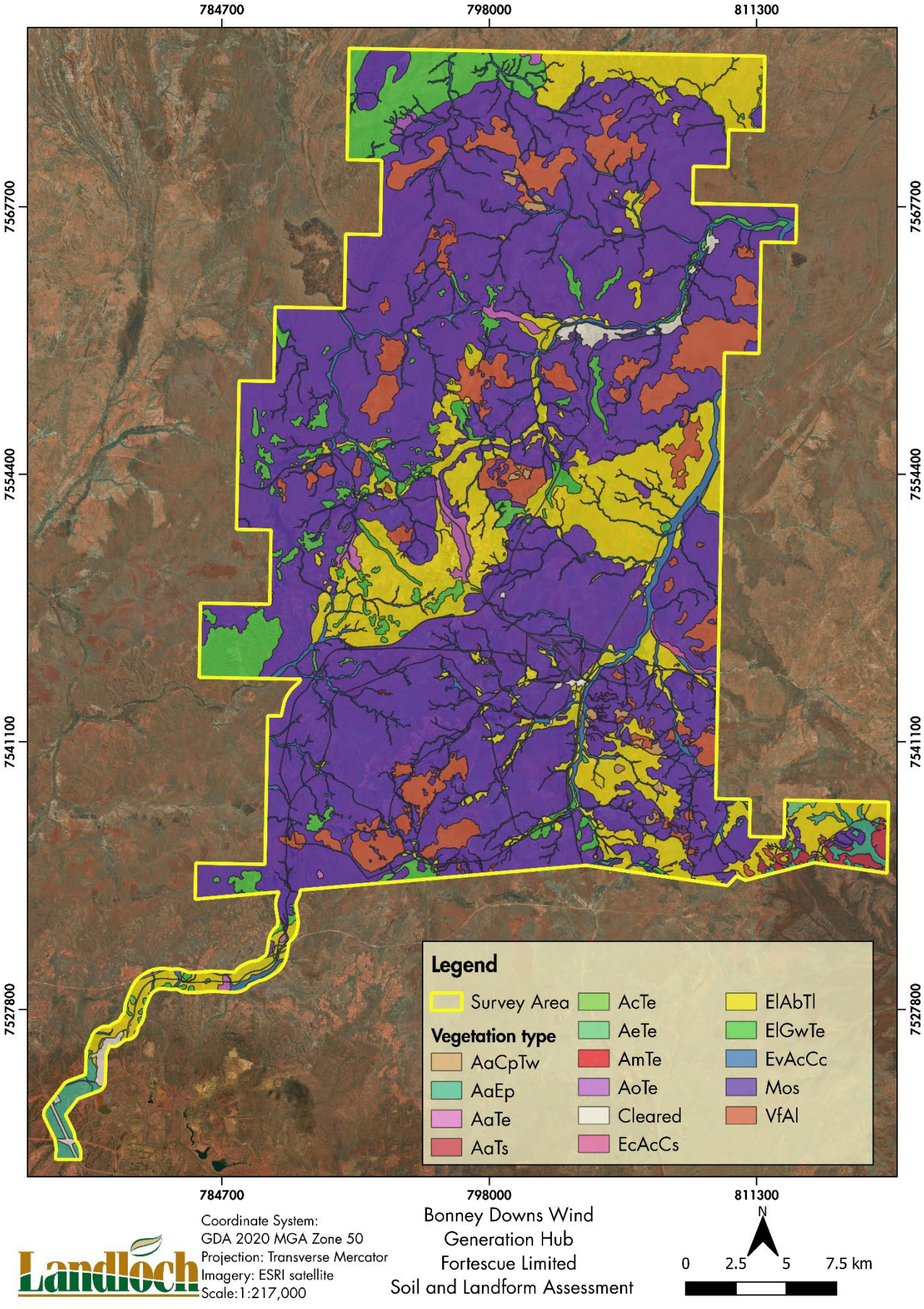

Figure 7: Vegetation unit mapping for the Survey area (Ecologia 2025a).

2.7 Terrestrial Vertebrate Fauna

Ecologia consolidated the results of terrestrial vertebrate fauna surveys of the Survey area (Ecologia 2025b). Alongside the detailed fauna assessment results, a fauna habitat assessment was completed. For each habitat identified, the following environmental descriptions were provided:

- Vegetation types;
- Basic soil descriptions; and
- Landform description.

A total of ten broad fauna habitat types were identified within the Survey area:

1. Rock Escarpments;
2. Plains (stony/gibber);
3. Plains (cracking clays),
4. Woodland (open);
5. Woodland (closed);
6. Drainage line/river/creek (major);
7. Drainage line/river/creed (minor);
8. Hill/Ranges/Plateaux;
9. Granite Outcrops (flat dome); and
10. Gorges/Gullies.

Of the ten habitat types, Ecologia identified Granite Outcrops as potentially providing microhabitats for significant fauna at both local and regional scale. The remaining nine habitat types were deemed to be common and widespread within the Pilbara.

The landform descriptions and photographs provided in the habitat descriptions have been correlated with the landform unit descriptions. Habitat descriptions and their associated landform units are provided in Table 22. The distribution of the habitats within the Survey area is shown in Figure 8.

The most prominent landform unit within the Survey area is Stony plains, occurring across 79% of the Survey area. This landform unit is associated with the Plain (stony/gibber) habitat.

Additionally, habitat descriptions provide an indication that most of the landform units are present within the Survey area. Three landform units are not associated to any of the habitat units. These landform units are:

- Lower slopes;
- Floodplains and terraces; and
- Groves.

Table 22: Fauna habitat units within the Survey area and associated landform units.

Habitat unit	Habitat description	Associated landform unit	Percentage of Survey area (%)
Plain (stony/gibber)	Stony sand on loam-clay undulating plains and low rises with spinifex hummock grasslands. Stony red clay soils present within this habitat. Both the Pilbara leaf-nosed bat, ghost bat and northern quoll forage in such areas. Additionally, provides habitat to the brush-tailed mulgara, Gane's blind snake, grey falcon, Pilbara olive python and western pebble-mound mouse.	Stony plains	79
Hills/Ranges/Plateaux	Habitat consisting of large ranges and hills with ridgelines and cliffs containing breakaways, boulders, crevices and caves. Such formations may provide shelter, denning, foraging and roosting habitats for various species. Such species include the northern quoll, Pilbara leaf-nosed bat and ghost bat.	Upper erosional surfaces	6
Plain (cracking clay)	Gilgai plains supporting scattered shrubs over grasses and herbs. Foraging habitat for various bird species. Provides habitat for northern short-tailed mouse. Noted degradation associated with grazing and trampling from cattle.	Gilgai plains	6
Drainage line/river/creek (minor)	Shallow incised drainage channels with an increased density of vegetation. This habitat is known to contain the grey falcon, short-tailed mouse and Pilbara leaf nosed bat.	Drainage lines and floors	2
Rocky Escarpments	Rocky features ranging from small rock faces to large protruding rocks/boulders and mesas. Typically associated with ridgelines, stony hills and rises. Potentially provided shelter, denning and roosting habitat for various species. Northern quoll, Pilbara leaf-nosed bay and western pebble-mound mouse were recorded in this habitat.	Upper erosional surfaces	2
Drainage line/river/creek (major)	Major drain lines and associated tributaries. Deeply incised drainage channels with a high density of vegetation. Gravelly sand and clay-loam soils. Scattered trees and shrubs provided bird habitats. Gost bat, grey falcon, norther quoll, Pilbara leaf-nosed bat and Pilbara olive pythons recorded within this habitat.	Drainage lines and floors	2
Woodland (closed)	Mulga woodlands associated with alluvial deposits. Containing woody debris that provides refuges for various burrowing species. Widespread habitat degradation associated with grazing and trampling from cattle.	Gilgai plains	1

Habitat unit	Habitat description	Associated landform unit	Percentage of Survey area (%)
Woodland (open)	Mulga woodlands associated with alluvial deposits. Containing woody debris that provides refuges for various burrowing species. Widespread habitat degradation associated with grazing and trampling from cattle. The grey falcon was recorded within this habitat.	Gilgai plains	1
Gorges/Gullies	Steep sided rocky habitats with breakaways, caves, crevices and cracks with a number of semi-permanent and permanent water sources. Woody debris and dense shrubbery provide shelter and habitat to ground dwelling species. Provides denning and roosting habitats for the northern quoll, Pilbara olive python, ghost bat and Pilbara leaf-nosed bat.	Upper erosional surfaces/ Drainage lines and floors	<1
Granite Outcrops	Cracks and crevices, overhangs and the underside of rocks may provide shelter and foraging areas for various species. Potentially utilised by northern quoll, Pilbara olive python and bat species.	Hills and rises	<1

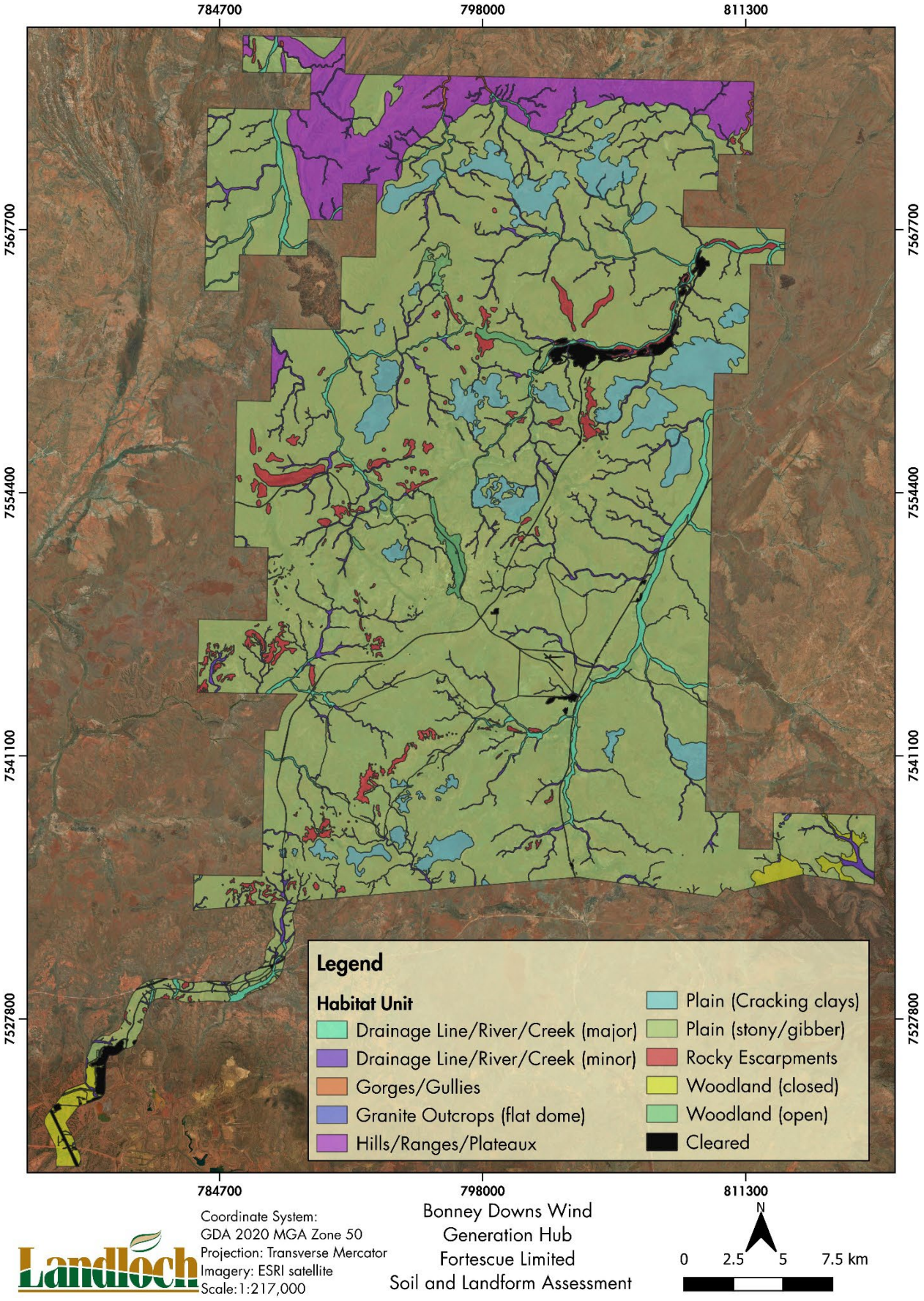

Figure 8: Terrestrial fauna habitat mapping for the Survey area (Ecologia 2025b)

2.8 Cultural Heritage Areas

The spatial extents of cultural heritage and culturally significant areas within the Survey area have been provided in the form of GIS files. The files have been sourced from the Department of Planning, Land and Heritage (DPLH), formerly the Department of Aboriginal Affairs (DAA).

A map of the registered cultural heritage areas, and their bounds, within the Survey area is provided in Figure 9.

An association between a number of heritage locations and landforms can be made. Most notably is the presence of numerous heritage footprints along the extents of various Drainage lines and floors. Additionally, a number of heritage areas are associated with two Upper erosional surface and Lower slope landform units. Areas that occur within the same location of Upper erosional surface landform units may potentially be associated with caves, which cannot be identified via aerial imagery or DEM analysis.

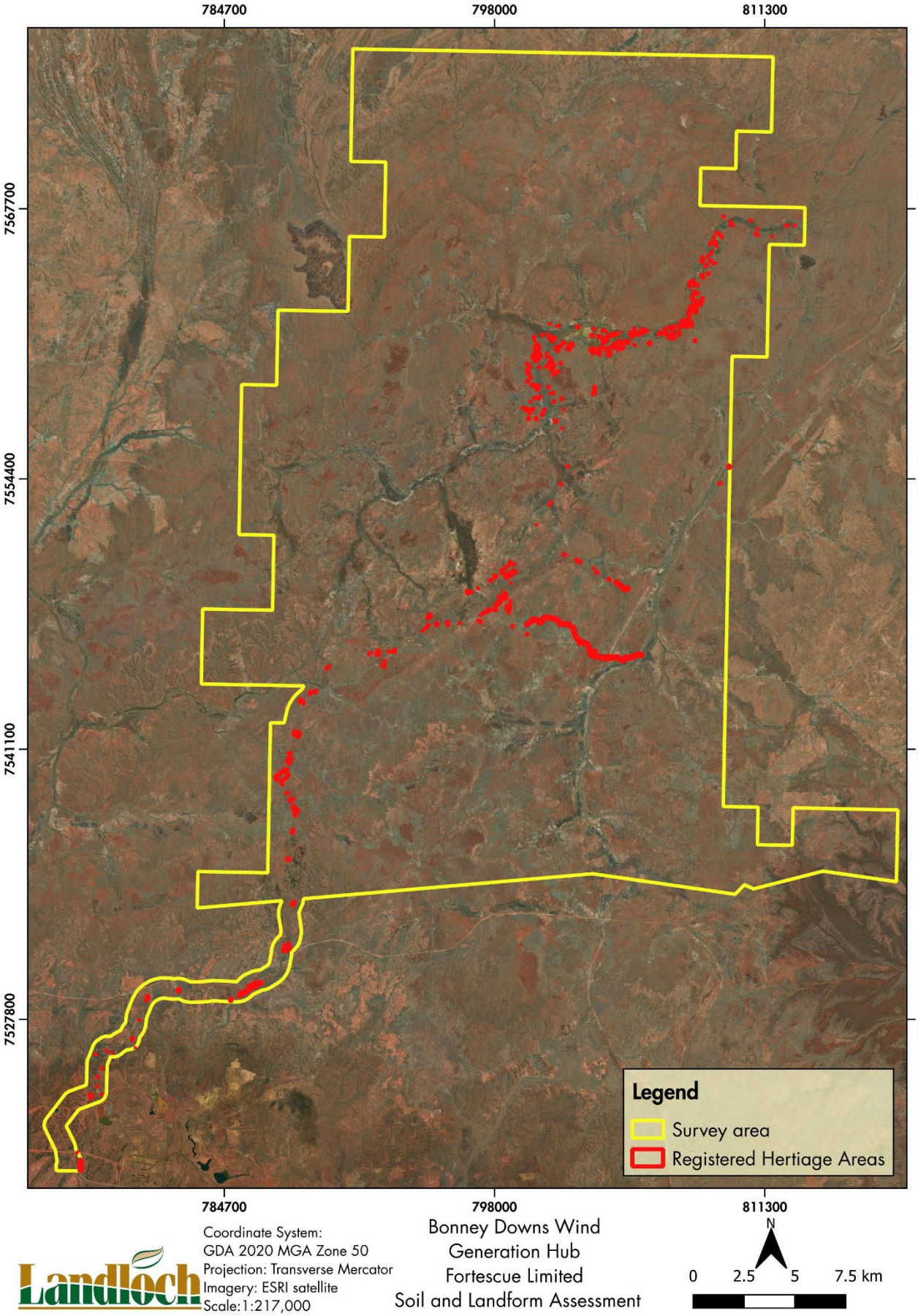

Figure 9: Cultural heritage mapping for the Survey area.

3 SOIL AND LANDFORM

3.1 Soils

Baseline soils data for *in situ* soils is limited to the area associated with the Nullagine Iron Ore Project, covered in Section 3.3. Using the limited data available, soil-landform associations were made to describe and map the soils of the Nullagine Iron Ore project area. This mapping covers 4% of the Survey area. For the remaining 96% of the Survey area, only broadscale regional scale soils data is available.

Based on the review of land systems (Vreeswyk *et al.* 2004) and soil landscape mapping (Northcote *et al.* 1960-68) four broad major soil types have been defined and mapped across the Survey area (Figure 10). The broad soil types are:

- Stony soils;
- Loamy earths;
- Self-mulching cracking clays; and
- Non-cracking clays.

The most prominent soil type is the Stony soils. These are typically shallow sandy or loamy soils with a high abundance of coarse fragments. These soils are formed by erosional processes and typically have very little to no soil structure. These features are typically found in areas with increased slope gradients, such as the tops of hills and rises, as well as on plateaux, mesas, and lower undulating plains. This soil type occurs in 7 of the 14 land systems and is estimated to be present across 72% of the Survey area.

Loamy earths are the major soil type of the Bonney, Jamindie and Spearhole land systems. This soil type is present across 19% of the Survey area. The Loamy earths are typically deep soils with an increased clay content in comparison to the Stony soils. Variability in soil depths occurs within this soil type, with shallower loams typically being associated with the presence of a hardpan layer.

Self-mulching cracking clays are present in the Wona and Turee land systems. This soil type occurs across 8% of the Survey area. These soils are typically deep red-clays that have shrink-swell properties. The presence of gilgai is indicative of such clays.

The non-cracking clays are associated only with the River and Elimunna land systems. This soil type is present across ~1% of the Survey area. The non-cracking clays are associated with the major drainage channel of the River land system. The soils are typically deep clays.

It is recommended that an infield baseline soil assessment be undertaken to ground truth the existing broadscale soils data. In particular, investigation of the soils associated with planned disturbance is required to provide soil handling recommendations based on the physical and chemical properties of the soils to be stripped.

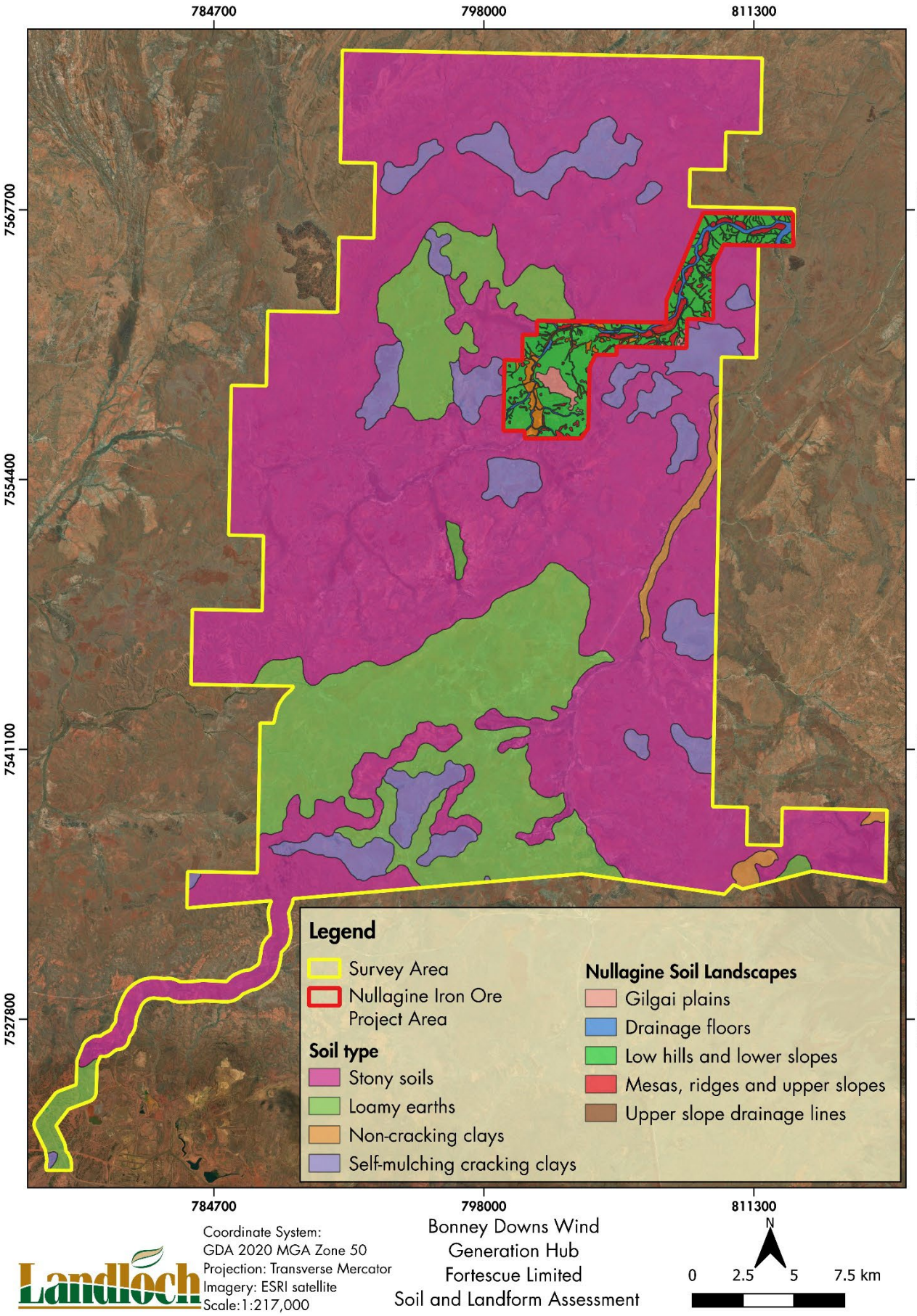

Figure 10: Distribution of soil types within the Survey area based on available data.

3.2 Landforms

Based on the assessment of land systems mapping, elevation, slope, vegetation mapping, and fauna habitat mapping, all of the landform units described except for Groves are likely to be present over the Survey area. An assessment of the presence of significant landforms was conducted across all landform units likely to be present over the Survey area. The potential distribution of the landform units within the Survey area is present in Figure 11.

3.2.1 Stony plains

Based on the available data, the Stony plains are present across approximately 60% of the Survey area. This landform unit occurs across various elevations and between different other landform units. This landform unit is not considered to be unique to the Survey area, as it is present throughout the Pilbara.

Stony plains provide important habitats and foraging grounds for various fauna species within the area, but not exclusively. The single significant vegetation type VfAl occurs in small areas within the Stony plains. A number of ethnographic and archaeologically heritage sites occur across the Stony plains.

3.2.2 Upper erosional surfaces

Erosional landform elements comprising plateaux, mesas, upper slopes and breakways are present across approximately 9% of the Survey area. The landforms dominate the northern reaches of the Survey area and are found throughout the Survey area. The presence of caves that provide habitat to wildlife was noted within the gorges and gullies.

A number of landforms within the landform unit are considered to be culturally significant. This may potentially include a number of caves occurring within gorges, gullies and ridges. There is potential for such features to occur where erosional landform elements interact with drainage lines and floors.

3.2.3 Gilgai plains

Gilgai plains are likely to occur across approximately 8% of the Survey area. This Landform unit is associated with self-mulching cracking clay soils and occurs in close proximity to the Stony plains, and Hills and rises landform units. The single significant vegetation type VfAl is associated with the Gilgai plains. One of the central Gilgai plains is associated with a large cultural heritage area, though no consistent relationship between the Gilgai plains and cultural heritage exists.

The association with the VfAl vegetation type and relative low abundance of Gilgai plains throughout the Pilbara suggests that this landform unit is potentially significant.

3.2.4 Hills and rises

The Hills and rises occur within approximately 12% of the Survey area. The Hills and rises occur throughout the Survey area. Typically, above the Stony plains and Gilgai plains. As erosional landforms, the Hills and rises may provide some scientifically significant insight into past geological processes.

3.2.5 Lower slopes

The Lower slopes cover approximately 6% of the Survey area. This landform unit occurs throughout the Survey area and are found down from the upper slopes of the Upper erosional surfaces landform unit. The Lower slopes are also associated with the Hills and rises, Stony plains, and Drainage lines and floors. A small number of archaeological and ethnographically culturally significant sites occur within this landform unit.

3.2.6 Drainage lines and floors

The Drainage lines and floors landform unit is present across approximately 4% of the Survey area. A number of major drainage channels occur throughout the Survey area. The largest of which is the Nullagine River found in the eastern region of the Survey area. The Nullagine River is the only Drainage lines and floors unit associated with the Floodplains and terraces landform unit. Typically, the Drainage lines and floors are associated with the Stony plains. In the north of the Survey area this landform unit is associated with the Upper erosional surfaces landform unit, occurring as part of the gullies and gorges described by Ecologia (2025a).

The Drainage lines and floors are culturally significant landforms to the Traditional Owners of the land. The majority of ethnographic cultural heritage areas occur along the Drainage lines and floors landform unit. From a tourism perspective, certain Drainage lines and floors, particularly those occurring in close association with the Upper erosional surfaces landform unit, also hold cultural significance.

Additionally, Drainage lines and floors only occur across 3% of the Pilbara region. The larger drainage channels such as the Nullagine River and Bonney creek are potentially significant within the regional setting.

3.2.7 Floodplains and terraces

Floodplains and terraces occur across approximately 1% of the Survey area. This landform unit occurs exclusively in association with the Nullagine River, a specific landform within the Drainage lines and floors unit. As these landforms are depositional there is little evidence of past ecological processes. Floodplains were not identified by the flora or fauna Surveys completed by Ecologia (2025a and 2025b).

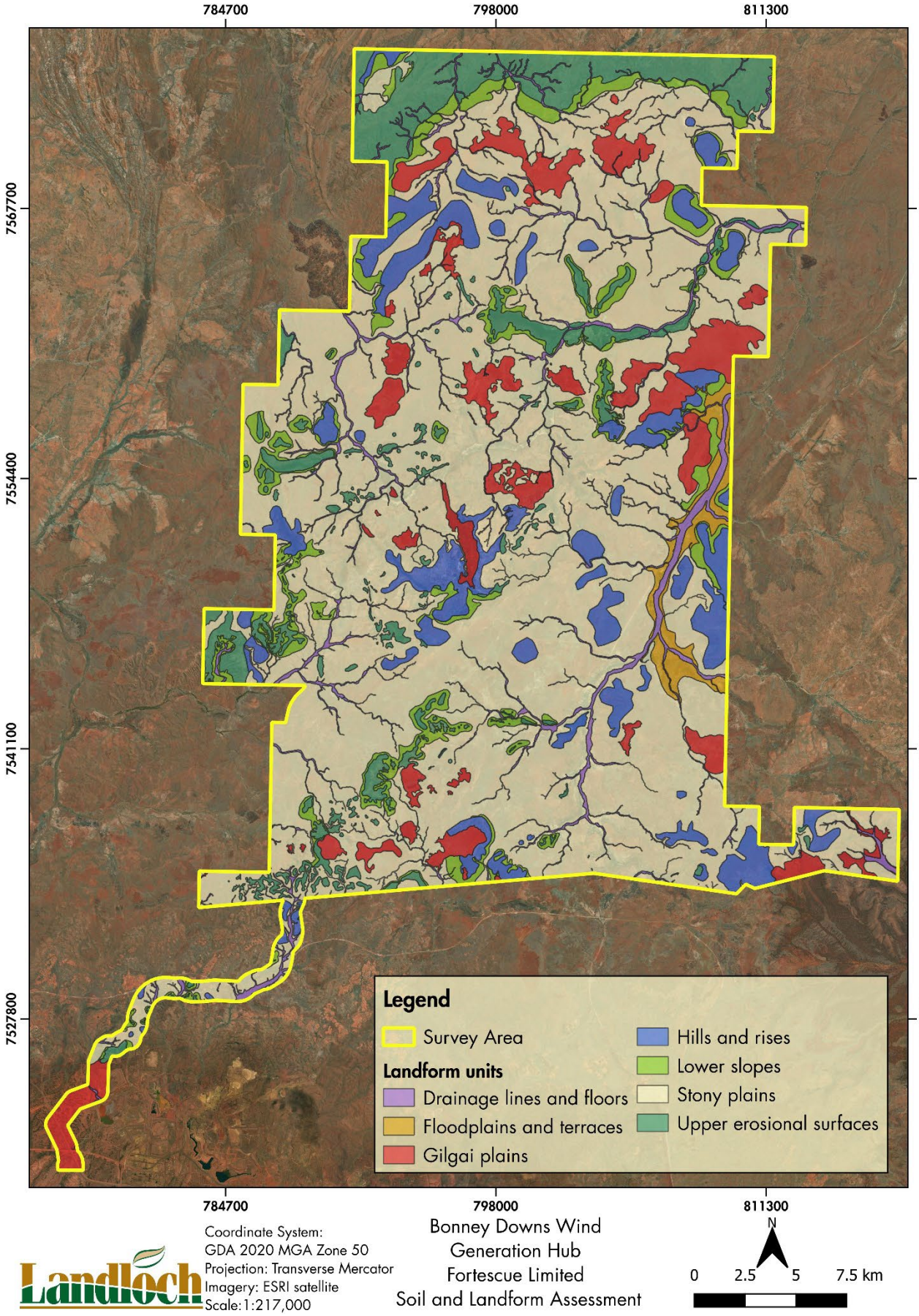

Figure 11: Landform unit mapping for the Survey area.

3.3 Acid sulphate soils

For ASS to occur, soils must be waterlogged (PASS) or have been waterlogged in the past (AASS). The Survey area contains multiple major and minor drainage lines and floors, which indicates that waterlogging may occur, or may have occurred in the past. This indicates that ASS is potentially present.

National ASS mapping has been completed at a variable scale which provides an indication as to the potential presence or absence of ASS (Fitzpatrick *et al.* 2011). For the Survey area, risk mapping indicates that there is a high probability (>70%) of PASS occurring within a combined area of approximately 28 ha. Approximately 11,660 ha of the Survey area is classed as having a low probability (6–70%) of occurrence of ASS. For the remaining 85,178 ha of the Survey area, risk mapping indicates that there is an extremely low probability (1–5%) of occurrence within the area. The area that is mapped as having a high probably of PASS is located along the river system found in the east, north-eastern extremes of the Survey area. National ASS mapping for the Survey area is shown in Figure 12. The confidence level of this mapping is noted as level 4.

Given that there is potential for ASS within the Survey area, particularly in areas associated with drainage channels, a preliminary assessment of ASS is recommended to be completed as part of any field Survey.

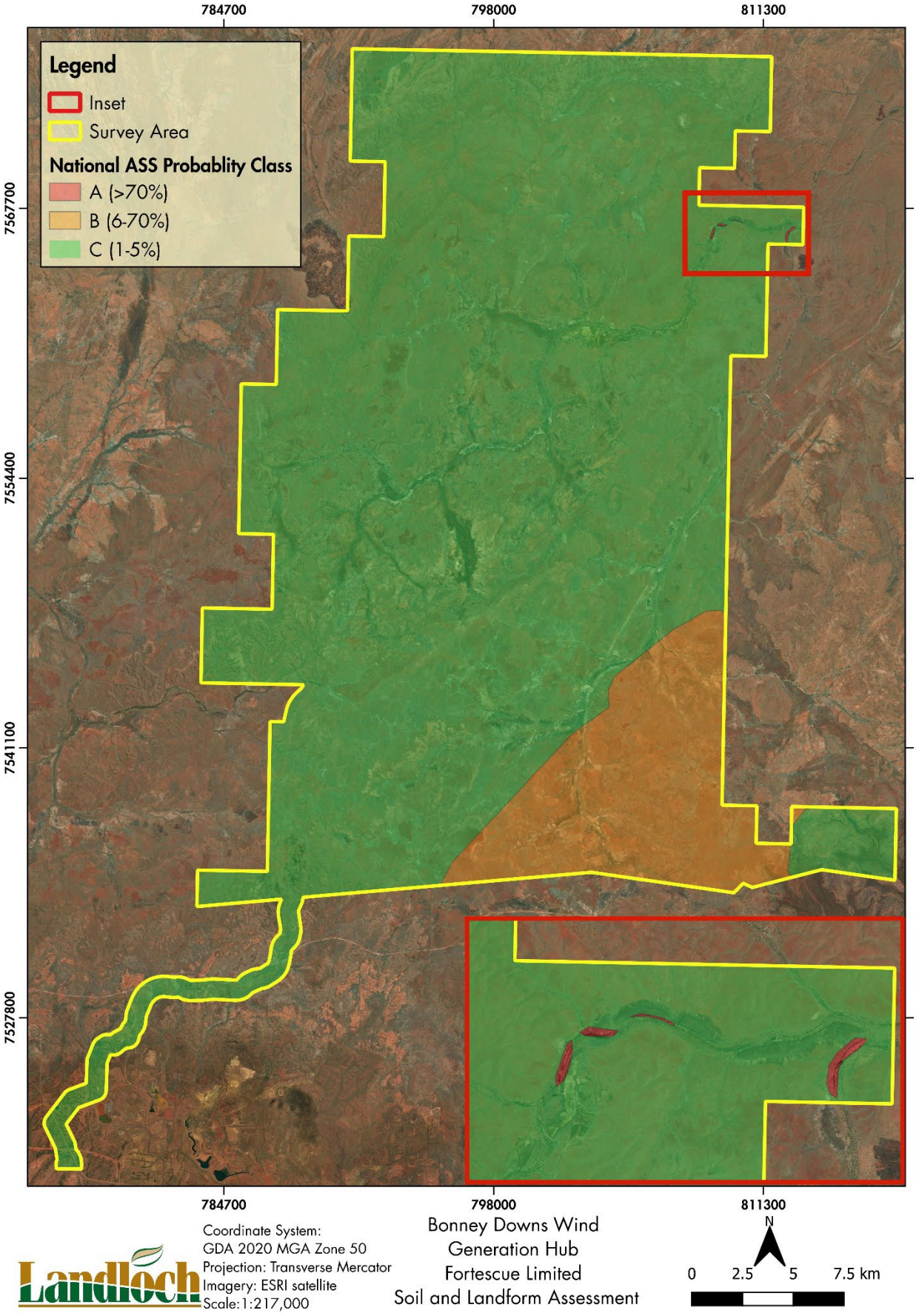

Figure 12: National Acid Sulphate Soil mapping (Fitzpatrick *et al.* 2011).

4 DISCUSSION

4.1 Landform Assessment

Based on the review of existing data concerning the landforms of the Survey area, an assessment of the significance was conducted for the landform units present over the area. This assessment is outlined in Table 23. It is noted that the designation of a landform as being potentially significant forms part of the feedback provided by the EPA as part of the EIA process. Ultimately, the EPA is the final authority on defining a landform as significant, and the desktop assessment completed by Landloch is provided from a guidance perspective only.

Of the landforms present within the Survey area, it is Landloch's view that three landform units present contain landforms that are considered potentially significant under the criteria set out by the EPA guidelines. The three landform units that contain landforms that are potentially significant are the Upper erosional surfaces, Gilgai plains and Drainage lines and floors units.

The mesas and plateaux of the Upper erosional surfaces landforms have an association with Banded Iron Formations (BIF) which is an indicator of significance as per the EPA. Additionally, gorges and gullies were noted by Ecologia (2025) to occur within this landform unit, such landforms have ecological and cultural significance as they provide habitats for wildlife and potential tourism attractions to the public. The presence of caves was noted by Ecologia, occurring at breakaways and gorges and gullies, that provide essential denning for wildlife, in particular bat species. Both caves and gorges and gullies occur throughout the Pilbara and are not regionally unique to the Survey area.

The Gilgai plains of the Survey area are potentially significant due to their association with significant flora, cultural heritage and regional representation. Significant flora occurs within the majority of the Gilgai plains of the Survey area. These factors indicate that the Gilgai plains of the Survey area are likely to be considered significant landforms.

The Drainage lines and floors landform unit potentially holds significant landforms. Many of the smaller drainage channels are designated at cultural heritage sites by the Traditional Owners. Additionally, major drainage channels such as the Nullagine River occur sparingly across the Pilbara. Such drainage channels are potentially significant within the regional setting.

From a variety perspective, no landform unit is unique to the Survey area. Gilgai plains and major Drainage lines and floors represent landforms that are uncommon within the Pilbara but are not unique to the Survey area.

Landloch's interpretation is based on the information available at the time of the desktop assessment and is solely based on a review of existing data. No in-field verification of landforms has been completed. As potentially significant landforms have been identified, a detailed in-field assessment of landform type is recommended.

Table 23: Assessment of landform significance.

Criteria	Stony plains	Upper erosional surfaces	Gilgai plains	Hills and rises
Variety	Stony plains occur across 8 land systems within the Pilbara. This is the most abundant landform unit of the Survey area (~58,000ha).	The erosional landforms are typically well represented locally and regionally. This landform unit covers ~8,500ha of the Survey area.	Occurs across three land systems within the Pilbara. Present within ~7,500ha of the Survey area.	Estimated to occur across ~12,000ha of the Survey area. Located in a number of areas across a variety of landforms.
Integrity	This landform is intact and in good condition at the local level.	This landform is typically intact and in varied condition at the local level. Disturbance is associated with the Nullagine Iron Ore mine. The northern landforms are undisturbed.	The Gilgai plains of the Survey area are intact and in good condition at the local level.	This landform is weathered and in varied condition.
Ecological importance	Potential habitat for various fauna species.	Provides denning for northern quoll, Pilbara olive python, ghost bat and Pilbara leaf-nosed bat.	This landform unit is associated with a priority ecological community	Potential habitat for various fauna species.
Scientific importance	Predominantly depositional landform, as such there is little evidence of past ecological processes.	As erosional landforms, may provide insight into past geological processes.	Predominantly depositional landform, as such there is little evidence of past ecological processes.	As erosional landforms, may provide insight into past geological processes.
Rarity	Described as 'very common' within the Pilbara be van Vreeswyck *et al.* (2004)	Present across multiple land systems within the Pilbara. Individual landforms such as caves and gorges have potential to be rare.	Uncommon within the regional setting. Occurring across ~8% of the Survey area.	Occurs within multiple land systems both locally and regionally.
Social importance	Ethnographic and archaeological heritage sites occur within this landform unit.	Various sites of cultural significance associated with this landform unit. Potential value for tourism.	Various sites of cultural significance occur across this landform unit.	Various sites of cultural significance occur across this landform unit.
Significance	**Unlikely to be significant.**	**Potentially significant.**	**Potentially significant.**	**Unlikely to be significant.**

Table 23 continued: Assessment of landform significance.

Criteria	Lower slopes	Drainage lines and floors	Floodplains and terraces
Variety	The Lower slopes are well represented locally, regionally and nationally. Present across ~5,700ha of the Survey area.	Varieties of drainage lines and floors occur throughout the Pilbara. Within the Survey area both major and minor channels occur. Estimated to cover ~4,100ha.	Floodplains and terraces occur within a single land system and are associated exclusively with the Nullagine river. Occurring across ~1,300ha.
Integrity	This landform is intact and in good condition at the local level.	This landform is intact and in good condition at the local level.	Floodplains are prone to degradation and erosion. Integrity assessment cannot be made at the desktop level.
Ecological importance	Potential habitat for various fauna species.	Major channels likely to be significant watercourses for the region.	Potential habitat for various fauna species.
Scientific importance	Depositional landform, as such there is little evidence of past ecological processes.	Depositional landform, as such there is little evidence of past ecological processes.	Depositional landforms, as such there is little evidence of past ecological processes.
Rarity	Present across multiple land systems within the Pilbara. Comprises ~6% of the Survey area.	Minor lines and floors occur extensively within the Pilbara. Major channels less common.	Described as 'common' within the Pilbara by can Vreeswyck *et al.* (2004).
Social importance	Culturally significant areas occur across this landform in small numbers.	Drainage lines (water) are considered culturally sensitive. Potential value for tourism.	No cultural heritage sites are mapped within this landform unit.
Significance	**Unlikely to be significant.**	**Potentially significant.**	**Unlikely to be significant.**

4.2 Terrestrial Environmental Quality Assessment

From a Terrestrial Environment Quality perspective, the soils broadly described across the Survey area are typical for Pilbara soils. Additionally, any disturbance of soil is likely to be restricted to the IDF. Without a baseline soils investigation of the soils within the Survey area, and more directly within the IDF, further conclusions concerning the physical and chemical properties of the soils cannot be made.

It is recommended that an in-field baseline soils investigation be undertaken to characterise the soils of the Survey area and IDF.

5 SUMMARY

5.1 Landforms

A desktop assessment of the landforms present over the Survey area has been completed following a review of regional and site-specific data. A large variety of individual landform types are present across the Survey area, to better manage this variation seven broad landform units were defined and assessed:

- Upper erosional surfaces (Plateaux, mesas, ridges, mountains and upper slopes);
- Stony plains;
- Hills and rises;
- Gilgai plains;
- Lower slopes;
- Floodplains and terraces; and
- Drainage lines and floors.

Based on the data review, a desktop assessment of the significance of the landforms was conducted for all landform units present over the Survey area.

Of the seven landform units potentially present within the Survey area, it is Landloch's view that three units present contain landforms that have potential to be considered significant under the criteria set out by the EPA guidelines. The Gilgai plains landform unit is potentially significant due to ecological and cultural importance. The Upper erosional surfaces are potentially significant due to their local rarity and variety, scientific and cultural importance. The Drainage lines and floors are potentially significant due to their cultural importance to the Traditional Owners.

5.2 Soils

Broadscale regional data and site specific data concerning the soils of the Survey area has been reviewed as part of this desktop assessment. Limited baseline soils data is available exclusively for the region associated with the Nullagine Iron Ore Project. Based on the review of soils data, the soils of the Survey area are likely to be similar to those found within the Pilbara region. No conclusions can be made concerning the impact that any disturbance will have on the soils with the available data.

An in-field assessment of the soils to ground truth the broadscale data is recommended. Such an investigation will provide data on the physical and chemical characteristics of the soils, which is of particular importance for areas of planned disturbance.

5.3 ASS

Based on a review of the National ASS mapping, there is a high chance of ASS occurring in an area associated with the Bonnie Creek and Nullagine river. There is a low chance of ASS occurring within the remaining Survey area.

It is recommended that in-field ASS/PASS testing be undertaken within the Survey area alongside any in-field soils assessments. As ASS are typically only problematic when they are disturbed, any ASS/PASS testing can be restricted to areas associated with future disturbance. ASS/PASS testing for areas within the Survey area but outside IDF may not be necessary.

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