DEPARTMENT OF
ENVIRONMENT AND
NATURAL RESOURCES

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# Land Resources of Charles Darwin University bushlands, Casuarina

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NORTHERN TERRITORY GOVERNMENT

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# Introduction

## 1.1 Background

In late 2016 to early 2017 the Land Assessment Branch of the Department of Environment and Natural Resources (DENR) was requested by Charles Darwin University (CDU) to map the land resources of the bushlands directly north-west of the Casuarina Campus. The Land Assessment Branch was initially approached by the CDU School of Environment to assist with mapping the area as part of their Conservation on Campus project. This project is a collaboration of staff, postgraduates and volunteers who are interested in increasing the knowledge and management practices of the flora and fauna at the back of the campus.

As such, the project objectives were to:

- aid with environmental management and rehabilitation of the native vegetation by volunteers and potentially Facilities/Operations Branch of the University;
- demonstrate Land Assessment procedures for Land unit mapping and present findings to relevant staff and students of the University;
- provide educational tools and training materials to aid teaching, future studies and research; and
- promote the use of publicly available data resources generated by NT DENR.

## 1.2 Study area

The bushlands of Casuarina campus make up about 8 ha between the campus buildings and Casuarina beach. In addition, an area of about 1 ha of the Casuarina Coastal Reserve adjacent to the CDU bushlands to the south-west was included as the area is an important corridor for flora and fauna. The bushland is dominated by savannah vegetation with small areas of closed monsoon vine forest in and near the Casuarina Coastal Reserve.


Figure 1.1 CDU bushlands study area, Casuarina Campus

## 1.3 Climate

Darwin has a tropical climate with distinct wet and dry seasons. The Wet season typically goes from November through to April and is characterised by high rainfall (mean Wet season rainfall of 1607.1 mm from 1941-2016), high humidity and hot temperatures (mean maximums of 30-40˚C and minimums of 20-25˚C) (BOM 2017). The Dry season makes up the rest of the year with minimal to no rainfall, decreased humidity and marginally cooler temperatures (mean maximums of 30-40˚C and minimums of 19-25˚C) (BOM 2017). The change from the Dry season to the Wet season is a period known as the 'build up', where humidity is intense, with little to no rain.

# 2. Methodology

## 2.1 Land unit mapping

Mapped polygons delineated during the study are homogeneous land units. Hooper (1970) defines these as “relatively uniform parts of a land surface, distinct from surrounding terrains and characterised by consistent landform, soil and vegetation properties”. Mapped land units typically exhibit a uniform pattern on aerial photography or satellite imagery and present as a repeatable and recognisable combination of landscape terrain, soil type and associated vegetation community. While some degree of variation is normally present within any land unit, such variation is usually too small or too inconsistent to map separately at the given survey scale. Land unit mapping within the Northern Territory occurs at various scales.

Preliminary landscape interpretation incorporating geological mapping, digital elevation model (DEM) analysis, imagery patterns and observable landscape features was used to delineate potential landform, soil and vegetation changes within the study area. Proposed field sampling locations were selected during this process. Preliminary linework boundaries were verified and/or adjusted during fieldwork and final linework was scanned and digitised following the completion of field investigations.

### *2.1.1 Mapping scale and accuracy*

Based on the size and the degree of landscape complexity expected within the study area, a published mapping scale of 1: 5 000 was deemed appropriate. Field survey intensities to validate spatial outcomes at this scale were considered both achievable and sufficiently thorough to satisfy the technical specifications required by the investigations terms of reference. Maps included with the report have been enlarged to a scale of 1: 2 000 for presentation purposes.

The accuracy and reliability of published mapping is determined by the density of ground observations and level of detail recorded. McKenzie *et al.* (2008) recommend that mapping at a scale of 1: 5 000 requires a minimum acceptable ground observation density of 1 observation per ha. This equates to about 9 total observations across the entire study area (9.3 ha). McKenzie *et al.* (2008) further suggests that at large mapping scales such as 1: 5 000, data collection should comprise 10-30% detailed soil profile descriptions and a further 1-5% representative sampled sites for laboratory analysis. The remaining ground observations (65-89%) should comprise map boundary observations that simply confirm delineated soil or land unit changes on the ground.

Due to the intended use of mapping and resources available in this project, no analytical testing has been carried out. As such, a greater emphasis has been put on collecting detailed field sites.

## 2.2 Field survey

The field program was undertaken in February 2017. In total, 12 detailed field sites were described. A further 8 map boundary observations were made.

Soil investigations were undertaken using a trailer mounted EZIPROBE Centurian soil coring rig. The EZIPROBE Centurian is a top drive hydraulically operated percussion rig capable of capturing and extracting relatively intact soil cores (EZIPROBE 2013). Profiles were extruded into sample trays in the field for immediate description and sampling. Disturbance was

minimal, other than minor compaction (<0.2 m) from percussion impact and limited core disruption from inversion and vibration during extrusion. The rig was used in accordance with the EZIPROBE Operation, Maintenance and Spare Parts Manual (EZIPROBE 2013), and field operations followed protocols specified within the EZIPROBE Standard Operating Procedures (DLRM 2014). Hand augered profiles were described where vehicle access was limited.

## 2.3 Soil descriptions

All field descriptions were collected in accordance with standards outlined by the National Committee on Soil and Terrain (2009), Hnatiuk *et al.* (2009) and Isbell (2017). Field observations recorded included geology/parent material, landform (pattern and element), slope, relief/modal slope class, substrate lithology, site disturbance, erosion features, microrelief, surface rock, surface condition, detailed soil profile morphology, site drainage and permeability characteristics, and vegetation characteristics (Section 2.4 below). Field assessment of soil profile morphology included description of soil horizons, boundaries, texture, colour, mottling, bleaching, structure, consistence, gravel, segregations and substrate material (where present); as well as field assessment of sodicity (where relevant), sand fraction, pH and EC.

### *2.3.1 pH and EC screening data for all detailed sites*

Salinity profiles generated from $EC_{1:5}$ measurements provide valuable information about leaching characteristics and subsoil salt loads within the landscape, and are particularly useful when determining effective rooting depth (ERD). Collection of such data across the majority of detailed field sites completed during the investigation has provided a comprehensive set of screening data spanning the entire study area. At tested sites, $pH_{1:5}$ and $EC_{1:5}$ measurements were completed for each soil horizon to characterise profile trends. Field $pH_{1:5}$ and $EC_{1:5}$ analyses follow the procedures described for Standard Methods 4A1 and 3A1 in Rayment and Lyons (2011). Field $pH_{1:5}$ and $EC_{1:5}$ data for each land unit is presented in Appendix 1.

## 2.4 Vegetation sampling and descriptions

Structural and floristic vegetation characteristics were recorded at each field site location within a 400 $m^2$ square sample area. Each sample area was located immediately adjacent to the soil assessment site in the direction judged to best represent the surrounding vegetation community.

Classification and description of vegetation communities within the study area uses standard conventions and terminology defined by the National Vegetation Information System (NVIS) (ESCAVI 2003) and the Australian Soil and Land Survey Handbook (NCST 2009).

Upper, middle and ground strata were identified in the field and the dominant growth form, percentage cover, average height, height range and basal count were recorded for each layer. In addition, percentage cover was recorded for individual species in each stratum. Cover values were visually estimated due to time restrictions. While this is a good representation of general vegetation structure and floristics, individual values should not be relied upon for high accuracy. Upper and mid strata were recorded as Crown Cover (%) while ground strata were recorded as Foliage Cover (%). A basal sweep using a basal

wedge (Bitterlich gauge) was also conducted at each site for woody species in the upper and mid stratum to determine species dominance ($m^2$/ha).

All collected vegetation data (noting any disturbance due to weeds or fire) was analysed together with soil and landscape information in order to finalise and define unique land units and vegetation communities presented in Chapter 5. For each land unit, the dominant vegetation community was further analysed to derive values for each stratum of average cover, cover range, height, height range and basal area. A list of all identified species from the CDU study area is presented in Appendix 2.

## 2.5 Data storage and availability

Field site records describing landform, soil morphology, soil chemistry and physical soil data from the study are stored in the Northern Territory's Soil and Land Information system (*SALInfo*). Vegetation information from each site is stored in the Northern Territory Vegetation Site Database (NTVSD).

Spatial data and map products are located within the Department's corporate spatial library and are available on request. The report for this project is available electronically from the Northern Territory library, while technical data, project findings and derived map products can be accessed and downloaded from the Department's web enabled data and information centre, *NR Maps*. http://nrmaps.nt.gov.au

The metadata for the spatial dataset can be sourced from the following link:

http://www.ntlis.nt.gov.au/metadata/export_data?type=html&metadata_id=56C27229314CB173E050CD9B21444136

# 3. Geology

The following sections outline the physiography, current drainage network and likely geologic evolution of the Darwin region as relevant to the CDU bushlands study area. The information presented describes the probable origins and present day characteristics of the surficial regolith, and has been sourced directly from the review by Pietsch (1983). Use of the published ideas and information from the author is gratefully acknowledged.

## 3.1 Physiography

The physiography of Darwin includes five terrains, with two land masses divided by Darwin Harbour. Two of the five physiographic terrains are spatially relevant to the CDU study area. The first is the Littoral Complex featured along the coastal plains and the second is the Plateau further inland.

The Littoral Complex consists of beach sands, cheniers, saline and calcic sands, and intertidal flats of silt and clay. The unit often features mangrove forests. This unit relates to the beach ridge plains of the CDU bushlands study area (Landscape 12).

The Plateau unit is a gradually sloping surface underlain by Cretaceous sediments that is dominated by sandy, gravelly soils. This unit relates to the low rises of the CDU bushlands study area (Landscape 7).

The two physiographic terrains within the study area are separated by an old relict alluvial plain that consists of soils developed from sandy, silty or clayey alluvium. This unit relates to the stream channels and stream banks of the alluvial plains (Landscape 9).

## 3.2 Drainage network

Drainage networks for the area intersecting and directly surrounding the CDU study area run generally north to south currently entering at Rapid Creek. There is evidence of an old intertidal stream channel that ran through the study area and exited onto the beach that is now present as a relict alluvial plain.

## 3.3 Geological evolution of the present landscape

Rock units that are associated with the two physiographic terrains and intersect the CDU bushlands study area are described in detail below from the oldest to most recent deposits. The characteristics and origins of each of the geologic entities are discussed; in particular the lithology and weathering status of surficially exposed units.

### *3.3.1 Proterozoic*

The Darwin region is uniformly underlain by Proterozoic rocks of the Burrell Creek Formation (Pfb). This formation is the youngest Early Proterozoic sedimentary unit in Darwin with surficial exposures at southern Shoal Bay Peninsula at the cliff base and as rubbly outcrop. Rock types within this formation are siltstone, shale, sandstone, quartz-pebble conglomerate and metamorphosed to lower greenschist facies. The depth of the Burrell Creek Formation is unknown.

### *3.3.2 Mesozoic*

The Darwin Member of the Bathurst Island Formation (Kld) formed in the Lower Cretaceous is an unconforming layer overlying the Burrel Creek Formation in most of the Darwin Region. The unconformity is the result of sediment deposition over the undulating often steeply dipping Proterozoic unit. Rock types within this formation are radiolarian claystone, sandy claystone, clayey sandstone, quartz-sandstone, ferruginous sandstone, glauconitic sandstone and basal conglomerate. The thickness of this unit varies from 2-40 m increasing to the north. It is recorded as 40 m thick with 25 m of weathering at Lee Point.

### *3.3.3 Cainozoic (superficial deposits)*

Widespread dissection and subsequent localised redistribution of stripped sediment during the late Tertiary has resulted in the formation of a relatively consistent, locally provenanced colluvial cover (Czs) across much of the Darwin region. The unit consists of laterite-related, sandy to clayey soils no greater than 3 m deep, predominantly developed from the underlying Cretaceous strata. Land units 7a, 7b1, 7b2 and 7c are associated with this colluvial cover.

Much of the soils around the CDU study area are sitting over deeply weathered intact cretaceous sediments (Czl) that have been laterized during the Cainozoic. The movement of water through the unit has resulted in a trizonal profile with ferricrete over a mottled zone and then a pallid zone. The pallid zone has been subject to the greatest amount of leaching of iron as a result of frequent inundation. Above it, the mottled zone has had a lower frequency of inundation resulting in the mobilisation but lesser leaching of iron causing mottling throughout the zone. The top ferricrete layer has had the least water exposure and iron oxides are able to build up.

Quaternary alluvium (Qa) cover is found in the relict alluvial plains of the CDU study area (Land unit 9a). The unit consists of stream channel deposits including gravel, sand and silt up to 2 m thick.

Coastal alluvium (Qca) is found in the intertidal creeks and intratidal flats of the CDU study area. The unit consists of mud, silt and clay that have been built up and aggraded by channelled tide-water flow.

Within the swales of the beach ridge plain soil is developed on beach rock (Qcb). Soils in this unit have been developed from beach ridge sand (Qcr) that has been reworked by natural and/ or artificial processes.

# 4. Landscapes

Three distinct landscapes (7- low rises, 9- alluvial plains, and 12- marine landscapes) are recognised within the CDU bushlands study area. Delineation of these landscapes is based on a combination of lithologic origins and landform differentiation. Landscape numbers are derived from Hill and Napier (2015).

Landscape 7 is associated with undulating, low broad rises within the gently dissected, deeply weathered landscape. Soils are developed on transported colluvial sediments (Czs/Czl) overlying deeply weathered Cretaceous sedimentary rocks (Kld). The depth of colluvial material is no greater than 4 m. Landscape 1 occupies the highest point of the survey area with hillslopes of 1-6%. The unit slopes down to the south-west with a relief of 9 m from the highest to lowest point within the survey area. Mapped land units include 7a, 7b1, 7b2 and 7c.

Variation in the landform and soil characteristics of Landscape 7 have arisen due to the non-uniform underlying substrate as well as varied transportation of sand throughout the landscape. Land unit 7a is distinguished by sandy surfaced, gradational soils showing evidence of a greater movement of sand than in other units. Land units 7b1 and 7b2 are loamy surfaced, gradational soils that differ from each other based on vegetation communities. Land unit 7c, despite being part of the low rises is subject to seasonal inundation caused by the non-uniform underlying substrate creating a pooling effect where rainfall cannot readily achieve lateral drainage from the profile.

Landscape 9 is associated with level relict alluvial plains that lie between the rises to the east and Quaternary deposits to the west. Soils are developed from sandy, silty or clayey alluvium, and are subject to flooding and/or poorly drained conditions during the Wet season. One land unit, 9a was mapped for this landscape, which is mapped to include both the stream channel and banks.

Landscape 12 is associated with beach ridge plains containing level floored open swales and tidal creeks. Soils within the swales are developed on Quaternary coastal ridge sands that have been reworked and contain beach rock (Qcb) (Land unit 12a). Soils within the tidal creeks are built-up and aggraded muds, silt and gravel (Land unit 12b). Land unit 12b is subject to flooding and/or poorly drained conditions during the Wet season.

# 5. Land units

## Land Unit 7a

**Summary:** Undulating, low broad rises with very deep, sandy surfaced, red or brown gradational earths overlying Cretaceous sedimentary rocks; Stringybark open woodland.

**Geology:** Unconsolidated Cainozoic cover overlying highly weathered, in-situ Cretaceous sedimentary rocks (Czs/Kld). Surficial lithology comprises an intact cover of unconsolidated, sandy/loamy sediments (over Cretaceous substrates at depth).

**Landform:** Undulating, low broad rises within the gently dissected, deeply weathered landscape, slopes of 2-6%.

**Soil concept:** Very deep (>1.5m) soft or firm, gravelly, sandy surfaced, massive red or brown gradational earths (clay loam sandy to medium clay subsoil).

**Aust. Soil Classification:** Red or brown Kandosols

**Runoff, perm., & drainage:** Slow to moderately rapid run off; slow to moderately permeable; imperfect to moderately well drained.

**Surface features:** Soft or firm; 60-90%; ironstone gravels (5-20mm); occasional rock outcrop; rare termitaria.

**Investigation area:** Total area mapped 2.4 ha (26% of 9.3 ha)

No. of field sites – 2 (sites 3,9)

### Dominant vegetation community – Stringybark Open Woodland

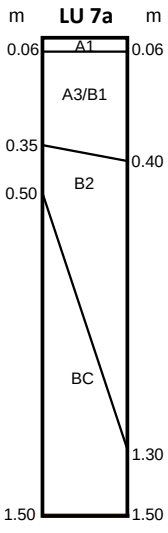
**NVIS Description:** Stringybark (*Eucalyptus tetrodonta*) mid open woodland over occasional Kakadu Plum (*Terminalia Ferdinandiana*) low woodland over Speargrass (*Sorghum intrans*) mid tussock grassland.

**Other notable species:** Upper: *Acacia auriculiformis*. Mid: *Syzygium eucalyptoides, Ficus aculeata, Cycas armstrongii*. Ground: *Andropogon gayanus, Petalostigma pubescens, Eriachne sp., Passiflora foetida.*

**Ecological state:** Doesn't appear to have been burnt for at least two years. Minor occurences of Gamba grass (Andropogon gayanus) of which some had been recently sprayed with herbicide.

| Strata | Growth Form | Cover (Range) % | Mean Height m (Range) | Mean Basal Area ($m^2$/ha) |
|---|---|---|---|---|
| **Upper** | Tree | 18 (16-20) | 12 (10-14) | 5.5 |
| **Mid** | Tree | 15 (6-25) | 5 (4-6) | 1.3 |
| **Ground** | Tussock Grass | 65 (40-90) | 1.0 (0.9-1.0) | - |

### Modal Soil Profile Description




The **surface soil** (A1) is a black (10YR 3/2, 7.5YR 2/1), loamy sand to sandy loam, with massive structure and sandy or earthy fabric; 40-50% 5-20mm ironstone gravels; field pH 6.0-7.5. Lower depth 0.06m; Clear change.

The **sub-surface layer** (A3/B1) is a black (7.5YR 3/2) or brown (10YR 4/4-4/6, 7.5YR 3/3), sandy loam to sandy clay loam; with massive structure and earthy fabric; 50-90% 5-20 mm ironstone gravels; field pH 6.0-7.5. Lower depth variation 0.35-0.4 m. Gradual change.

The **upper subsoil** (B2) is a brown (7.5YR 5/6) or red (5YR, 2.5YR 5/6), mottled (2-20% 5mm distinct red and yellow substrate mottles), clay loam sandy to light medium clay; with massive structure and earthy fabric; 45-80% 5-20mm ironstone gravels; field pH 6.0-7.5. Lower depth variation 0.5-1.3m. Clear change.

The **lower subsoil** (BC) is a red (5YR 5/6, 2.5YR,10R 4/6), mottled (50% 10mm distinct yellow and grey substrate mottles) clay loam sandy to medium clay; with massive structure and earthy fabric;50%; 5-20mm ironstone gravels; evidence of weathering substrate in soil matrix; field pH 5.5-6.0. Profiles are deeper than 1.5 m.

## Land Unit 7b1

**Summary:** Undulating, low broad rises with very deep, loamy surfaced, red or yellow gradational earths overlying Cretaceous sedimentary rocks; Kakadu Plum or Coffee Bush low woodland.

**Geology:** Unconsolidated Cainozoic cover overlying highly weathered, in-situ Cretaceous sedimentary rocks (Czs/Kld). Surficial lithology comprises an intact cover of unconsolidated, sandy/loamy sediments (over Cretaceous substrates at depth).

**Landform:** Undulating, low broad rises within the gently dissected, deeply weathered landscape, slopes of 2-6%.

**Soil concept:** Very deep (>1.5m), firm or hardsetting, gravelly, loamy surfaced, massive red or yellow gradational earths (light clay to light medium clay subsoil).

**Aust. Soil Classification:** Brown or yellow Kandosols

**Runoff, perm., & drainage:** Slow run off; slowly permeable; imperfectly drained.

**Surface features:** Firm or hardsetting, 10-90% ironstone gravels (3-20mm), no outcrop, occasional termitaria.

**Investigation area:** Total area mapped –2.3 ha (25% of 9.3 ha)

No. of field sites – 2 (sites 1,4)

### Dominant vegetation community – Kakadu Plum or Coffee Bush low woodland

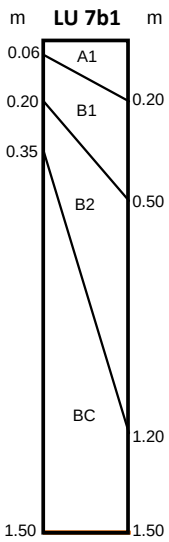
**NVIS Description:** Kakadu Plum (*Terminalia ferdinandiana*) low woodland over Speargrass (*Sorghum intrans*) mid closed tussock grassland OR Coffee Bush (*Leucaena leucocephala*) low woodland with emergent Apple Gum (*Corymbia polysciada*) and Black Wattle (*Acacia auriculiformis*).

**Other notable species:** Upper: *Lophostemon lactifluus.* Mid: *Ficus aculeata, Planchonia careya, Pandanus spiralis, Melaleuca viridiflora.* Ground: *Rottboellia cochinchinensis, Andropogon gayanus.*

**Ecological state:** Long unburnt with small infestations of Gamba Grass (*Andropogon gayanus*), some of which is recently sprayed with herbicide. The southern end of this land unit has been displaced by the invasive Coffee Bush (*Leucaena leucocephala*).

| Strata | Growth Form | Cover (Range) % | Mean Height m (Range) | Mean Basal Area ($m^2$/ha) |
|---|---|---|---|---|
| **Upper** | Tree | 39 (25-48) | 7 (6-9) | 3.0 |
| **Mid** | Tree/Shrub | 3 (1-5) | 3 (2-4) | - |
| **Ground** | Tussock Grass | 60 (40-80) | 0.9 (0.6-1.2) | - |

### Modal Soil Profile Description

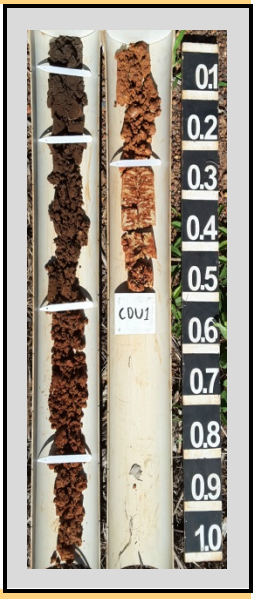



The **surface soil** (A1) is a black (10YR, 7.5YR 2/2, 3/2), loam to clay loam sandy, with massive to weak structure and earthy fabric; 2-5% 3-5mm ironstone gravels; field pH 5.0-6.0. Lower depth variation 0.06-0.2m; Clear change.

The **sub-surface layer** (B1) is a brown (10YR 4/3, 7.5YR 3/4), light clay to light medium clay; with massive to weak structure and earthy fabric; 40-50% 3-25mm ironstone gravels; field pH 5.0-6.0. Lower depth variation 0.2-0.5 m. Clear change.

The **upper subsoil** (B2) is a brown (7.5YR 5/6) or yellow (10YR 6/4), mottled (5-40%, 5-20mm prominent red and yellow substrate mottles) light clay to light medium clay; with massive to weak structure and earthy fabric; 40% 3-25mm ironstone gravels or nodules; field pH 5.0-6.0. Lower depth variation 0.35-1.2m. Clear to gradual change.

The **lower subsoil** (BC) is a red (2.5YR 4/6, 10R 3/6, 4/8), mottled (30-50% 10-40mm prominent yellow and grey substrate mottles), light clay to light medium clay; with massive structure and earthy fabric; 2-10% 10-25mm ironstone gravels; evidence of weathering substrate in soil matrix; field pH 5.0-6.0. Profiles are deeper than 1.5 m.



## Land Unit 7b2

**Summary:** Undulating, low broad rises with moderately deep, loamy surfaced, yellow gradational earths overlying Cretaceous sedimentary rocks; Stringybark woodland.

**Geology:** Unconsolidated Cainozoic cover overlying highly weathered, in-situ Cretaceous sedimentary rocks (Czs/Kld). Surficial lithology comprises an intact cover of unconsolidated, sandy/loamy sediments (over Cretaceous substrates at depth).

**Landform:** Undulating, low broad rises within the gently dissected, deeply weathered landscape, slopes of 2-6%.

**Soil concept:** Moderately deep (0.5-1.0m), firm, gravelly, loamy surfaced, massive yellow gradational earths (light clay subsoil).

**Aust. Soil Classification:** Yellow Kandosols

**Runoff, perm., & drainage:** Slow run off; slowly permeable; imperfectly drained.

**Surface features:** Firm, 55% ironstone gravels (5-20mm), no outcrop, occasional termitaria.

**Investigation area:** Total area mapped 1.0 ha (11% of 9.3 ha)

No. of field sites – 1 (site 5)

### Dominant vegetation community – Stringy bark woodland

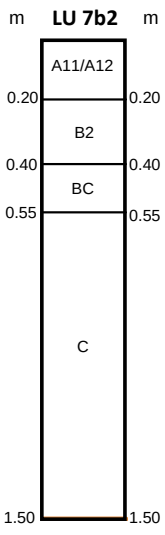
**NVIS Description:** Stringybark (*Eucalyptus tetrodonta*), Black Wattle (*Acacia auriculiformis*), Apple Gum (*Corymbia polysciada*) mid woodland.

**Other notable species:** Mid: *Terminalia ferdinandiana*, *Planchonia careya*. Ground: *Pandanus spiralis, Ampelocissus acetosa, Andropogon gayanus, Scleria sp., Ficus aculeata, Tacca leontopetaloides.*

**Ecological state:** Doesn't appear to have been burnt for at least two years. Minor occurences of Gamba Grass (*Andropogon gayanus*).

| Strata | Growth Form | Cover (Range) % | Mean Height m (Range) | Mean Basal Area ($m^2$/ha) |
|---|---|---|---|---|
| **Upper** | Tree | 45 (40-50) | 16 (14-18) | 8.5 |
| **Mid** | Tree | 3 (2-4) | 3 (2-4) | 2.0 |
| **Ground** | Vine | 40 (35-45) | 0.5 (0.4-0.6) | - |

### Modal Soil Profile Description




The **surface soil** (A11/A12) is a black (10YR 3/1-3/2), loam to clay loam sandy, with massive structure and earthy fabric; 7-50% 5-25mm ironstone gravels; field pH 5.0-6.0. Lower depth 0.2m; Clear change.

The **upper subsoil** (B2) is a yellow (10YR 6/4), mottled (10%, 5mm distinct pale and red substrate mottles), light clay; with massive structure and earthy fabric; 60% 8-25mm ironstone gravels; field pH 5.0-5.5. Lower depth 0.40 m. Gradual change.

The **lower subsoil** (BC) is a red (2.5YR 4/8), mottled (35%, 10-20mm distinct pale, yellow and orange substrate mottles), light clay; with massive structure and earthy fabric; 60%; 8-25mm ironstone gravels; field pH 5.0-5.5. Lower depth 0.55m. Clear change.

The **underlying substrate** (C) comprises a red, heavily mottled (pale, yellow and orange), highly weathered ferruginized sandstone fraction within a matrix of 90% hard ironstone and ferruginized sandstone gravels (10-30mm).

## Land Unit 7c

**Summary:** Undulating, low broad rises with moderately deep, loamy surfaced, brown or yellow gradational earths overlying Cretaceous sedimentary rocks; Apple Gum open woodland.

**Geology:** Unconsolidated Cainozoic cover overlying highly weathered, in-situ Cretaceous sedimentary rocks (Czs/Kld). Surficial lithology comprises an intact cover of unconsolidated, sandy/loamy sediments (over Cretaceous substrates at depth).

**Landform:** Undulating, low broad rises within the gently dissected, deeply weathered landscape, slopes of 1-3%.

**Soil concept:** Moderately deep (0.5-1.0m), soft or firm, gravelly, loamy surfaced, massive brown or yellow gradational earths (clay loam sandy to medium clay subsoil). Subject to seasonal inundation.

**Aust. Soil Classification:** Kandosolic Hydrosols

**Runoff, perm., & drainage:** Slow run off; slow to moderately permeable; poorly drained.

**Surface features:** Soft or firm, occasional 5-10% ironstone gravels (5-10mm), no outcrop, rare termitaria.

**Investigation area:** Total area mapped 1.7 ha (18% of 9.3 ha)

No. of field sites – 3 (sites 2,10,11)

### Dominant vegetation community – Apple Gum open woodland

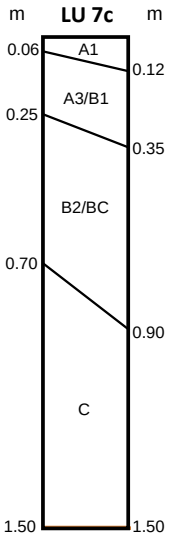
**NVIS Description:** Apple Gum (*Corymbia polysciada*) mid open woodland over occasional low woodland of Kakadu Plum (*Terminalia ferdinandiana*), Red Paperbark (*Lophostemon lactifluus*) and Syzygium (*Syzygium eucalyptoides*) over various tall sparse shrubs over variable mid tussock grassland (often dominated by Northern Cane Grass (*Mnesithea rottboellioides*) or vineland.

**Other notable species:** Mid: *Leucaena leucocephala, Melaleuca viridiflora, Ficus aculeata, Pandanus spiralis, Planchonia careya.* Ground: *Heteropogon triticeus, Ampelocissus acetosa, Cayratia trifolia, Passiflora foetida*.

**Ecological state:** Some areas appear to have been been burnt within the last two years. Minor ocurances of invasive Coffee Bush (*Leucaena leucocephala*) and various vines.

| Strata | Growth Form | Cover (Range) % | Mean Height m (Range) | Mean Basal Area ($m^2$/ha) |
|---|---|---|---|---|
| **Upper** | Tree | 18 (12-25) | 11 (9-12) | 4.0 |
| **Mid** | Tree/Shrub | 21 (8-20) | 5 (5-6) | 1.7 |
| **Ground** | Tree | 70 (15-60) | 1 (0.3-1.8) | - |

### Modal Soil Profile Description

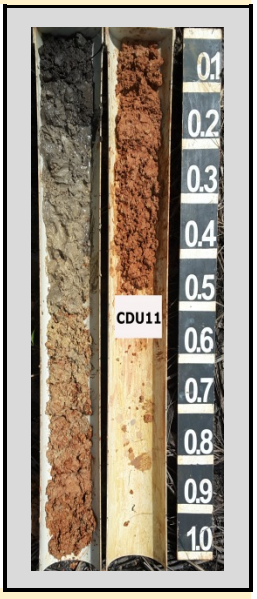



The **surface soil** (A1) is a black (5Y 2.5/1, 10YR 3/1), silty loam to light clay, with massive to moderate structure and earthy fabric; occasional 10% 25mm ironstone gravels; field pH 5.5-6.5. Lower depth variation 0.06-0.12m; Clear to gradual change

The **sub-surface layer** (A3/B1) is a black (5Y 3/1, 10YR 3/2) or grey (5Y 4/1), sandy loam to light clay; with weak to massive structure and earthy fabric; common 5-15% 3-10mm ironstone gravels; field pH 5.0-6.0. Lower depth variation 0.25-0.35 m. Gradual to clear change.

The **subsoil** (B2/BC) is a brown (2.5Y 5/4), yellow (2.5Y, 10YR 6/4, 7/4) or grey (5Y 4/2), mottled (20-60% 3-10mm prominent brown, orange and red substrate mottles); clay loam sandy to medium clay; with massive structure and earthy fabric;10-35%; 3-25mm ironstone gravels; field pH 5.0-6.0. Lower depth variation 0.7-0.9m. Clear to gradual change

The **underlying substrate** (C) comprises a grey or brown, heavily mottled (grey, brown, orange and red), highly weathered fraction within a matrix of 80-90% hard ferruginized sandstone material (10-30mm).



## Land Unit 9a

| | |
|---|---|
| **Summary:** | Stream channel and banks of relict alluvial plain, currently artificial drainage feature, disturbed soil and vegetation. |
| **Geology:** | Quaternary alluvium (Qa) cover consisting of stream channel deposits including gravel, sand and silt up to 2 m thick. |
| **Landform:** | Stream channel and banks of relict alluvial plain, slopes of <0.5% (greater slopes up banks). Subject to seasonal inundation. |
| **Aust. Soil Classification:** | Hydrosols |
| **Runoff, perm., & drainage:** | Slow run off; slowly permeable; poorly drained. |
| **Surface features:** | Soft, rare gravel (varied due to disturbance), no outcrop, rare termitaria. |
| **Disturbance:** | Field evidence suggests the original alluvial stream channel associated with this unit has undergone considerable earthworks and been further incised with machinery at some stage. It is likely this has been undertaken to create an improved artificial drainage feature to facilitate the removal of excess surface water from the surrounding areas, particularly access tracks (bike and walking) between the university and beach. This has resulted in the colonisation of non-native plant species mixed in with remnant species on stream banks. As such, the disturbed soil and vegetation is not typical of the original alluvial stream and therefore was not sampled. |
| **Investigation area:** | Total area mapped –0.3 ha (3% of 9.3 ha)<br>No. of field sites – 0 (too disturbed) |

## Land Unit 12a

**Summary:** Relict Aeolian derived level swale, with moderately deep to deep, loamy surfaced brown earthy sands overlying beach rock; Pongamia, Micromelum and/or Coffee Bush low closed (monsoon vine) forest.

**Geology:** Soils developed from beach ridge sand (Qcr) overlying beach rock (Qcb).

**Landform:** Relict Aeolian derived level swale within a broader beach ridge plain, slopes 0.5-2%.

**Soil concept:** Moderately deep to deep (0.5-1.5m), soft or firm, sapric (organic), loamy surfaced, massive brown earthy sands (loamy sand to sandy loam subsoil) overlying beach rock.

**Aust. Soil Classification:** Brown-Orthic Tenosols

**Runoff, perm., & drainage:** Moderately rapid run off; moderately permeable; moderately well to well drained.

**Surface features:** Loose to soft, no gravel, no outcrop, rare termitaria.

**Investigation area:** Total area mapped 1.4 ha (15% of 9.3 ha)

No. of field sites – 3 (sites 6,8,12)

### Dominant vegetation community – Pongamia, Micromelum and/or Coffee Bush low closed (monsoon vine) forest

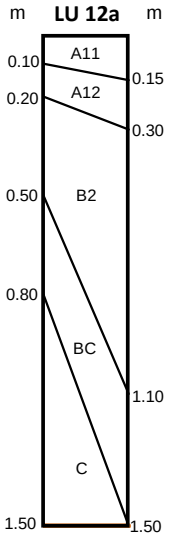
**NVIS Description:** Pongamia (*Millettia pinnata*), Micromelum (*Micromelum minutum*) low closed forest with emergent Black Wattle (*Acacia auriculiformis*) with large areas almost completely dominated by mature Coffee Bush (*Leucaena leucocephala*).

**Other notable species:** Mid: *Bombax ceiba*, *Flueggea virosa*, *Ganophyllum falcatum*, *Wrightia pubescens, Sterculia quadrifida, Smilax australis, Ipomoea sp., Stephania japonica.* Ground: *Murraya koenigii.*

**Disturbance:** This land unit is long unburnt. A large portion has been displaced by invasive Coffee Bush (*Leucaena leucocephala*), forming exclusive mature stands of closed forest.

| Strata | Growth Form | Cover (Range) % | Mean Height m (Range) | Mean Basal Area ($m^2$/ha) |
|---|---|---|---|---|
| **Upper** | Tree | 82 (80-85) | 10 (9-12) | 7.0 |
| **Mid** | Tree | 18 (10-25) | 6 (5-6) | 0.3 |
| **Ground** | Tree (regrowth) | 12 (5-15) | 0.7 (0.5-0.8) | - |

### Modal Soil Profile Description




The upper **surface soil** (A11) is a black (5YR 2/2-3/2), or brown (10YR 3/3), sapric sandy loam to loam, with massive to weak structure and earthy fabric; non-gravelly; field pH 7.0-8.5. Lower depth variation 0.10-0.15m; Gradual change.

The lower **surface soil** (A12) is a brown (7.5YR 3/3) or red (5YR 3/3), sapric loamy sand to sandy clay loam with massive structure and earthy fabric; 10-40% 5-50mm beach rock gravels; field pH 7.5-8.5. Lower depth variation 0.2-0.3m. Clear to gradual change.

The upper **subsoil** (B2) is a brown (7.5YR 3/4, 4/6) or red (10R 4/6), sand to sandy loam with massive structure and sandy or earthy fabric; 30-60% 5-50mm beach rock gravels; field pH 8.0-9.0. Lower depth variation 0.5-1.1m. Clear to gradual change.

The lower **subsoil** (BC) is a brown (7.5YR 4/6, 5/6) or red (10R 4/6), sand to loamy sand; with massive structure and sandy or earthy fabric; 70%; 5-50mm beach rock gravels; field pH8.5-9.0. . Lower depth variation 0.8->1.5m. Clear change.

The **underlying substrate** (C) comprises a brown highly weathered fraction within a matrix of 90% hard beach rock material (5-50mm).

## Land Unit 12b

**Summary:** Intertidal creek and associated intratidal flats, with moderately deep to very deep, sandy surfaced red earthy sands overlying beach rock; Coffee Bush woodland.

**Geology:** Coastal alluvium (Qca) cover built up and aggraded by channelled tide-water flow overlying beach rock (Qcb).

**Landform:** Intertidal creek and associated intratidal flats within a broader beach ridge plain, formed from marine deposition, slopes <1% (increasing to 2-3% at banks).

**Soil concept:** Moderately deep to very deep (0.5->1.5m), soft, sapric (organic), sandy surfaced, massive red earthy sands (clayey sand subsoil) overlying beach rock.

**Aust. Soil Classification:** Intratidal Hydrosols

**Runoff, perm., & drainage:** Very slow run off; highly permeable; very poorly drained.

**Surface features:** Soft, no gravel, no outcrop, no termitaria.

**Investigation area:** Total area mapped 0.2 ha (2% of 9.3 ha)

No. of field sites – 1 (site 7)

### Dominant vegetation community – Coffee Bush woodland

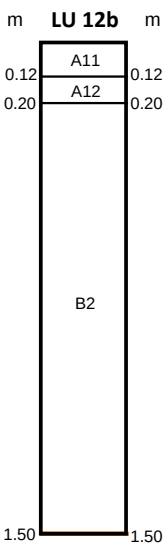
**NVIS Description:** Coffee Bush (*Leucaena leucocephala*), Apple Gum (*Corymbia polysciada*) mid woodland over Pandanus (*Pandanus spiralis*), Bean Tree (*Cathormion umbellatum*), Beach Hibiscus (*Hibiscus tiliaceus*) low woodland.

**Other notable species:** Mid: *Cayratia trifolia, Passiflora foetida.* Ground: *Smilax australis, Terminalia microcarpa, Taca leontopeloides, Sorghum sp.*.

**Ecological state:** Much of this land unit is dominated by invasive Coffee Bush (*Leucaena leucocephala*).

| Strata | Growth Form | Cover (Range) % | Mean Height m (Range) | Mean Basal Area ($m^2$/ha) |
|---|---|---|---|---|
| **Upper** | Tree | 40 (35-45) | 12 (11-13) | 5.0 |
| **Mid** | Tree/Palm | 30 (25-35) | 5 (4-6) | 7.0 |
| **Ground** | Tree/Palm (regrowth) | 25 (20-30) | 0.7 (0.5-0.9) | - |

### Modal Soil Profile Description




The upper **surface soil** (A11) is a black (10YR 2/1), sapric sandy loam, with massive structure and earthly fabric; non-gravelly; field pH 6.0-6.5. Lower depth 0.12 m. Gradual change.

The lower **surface soil** (A12) is a black (10YR 2/1), sapric sandy loam, with massive structure and earthly fabric; 5% 5mm sandstone gravels; field pH 6.0-6.5. Lower depth 0.20 m. Clear change.

The **subsoil** (B2) is a red (2.5YR 4/8), clayey sand; with massive structure and sandy or earthy fabric; 35% 5-10mm sandstone and beach rock gravels; field pH 6.0-6.5.

Profiles depth unknown due to complete saturation of soils. Likely to have a range of depths onto beach rock similar to Land unit 12a.

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# Appendix 1 pH and EC site data for CDU bushlands study area

| Land unit | Site | Horizon | pH | EC (ds/cm) |
|---|---|---|---|---|
| **7a** | 3 | A1 | 6.1 | 0.02 |
| | | A3 | 5.9 | 0.02 |
| | | B1 | 5.7 | 0.02 |
| | | B2 | 5.9 | 0.02 |
| | | BC | 5.5 | 0.03 |
| | 9 | A1 | 7.7 | 0.09 |
| | | A31 | 7.5 | 0.05 |
| | | A32 | 7.3 | 0.06 |
| | | B21 | 7.4 | 0.04 |
| | | B22 | 6.8 | 0.04 |
| | | BC | 5.6 | 0.05 |
| **7b1** | 1 | A1 | 5.8 | - |
| | | B1 | 6.0 | - |
| | | B2 | 6.0 | - |
| | | BC | 6.0 | - |
| | 4 | A1 | 5.2 | 0.02 |
| | | B1 | 5.2 | 0.02 |
| | | B2 | 5.0 | 0.03 |
| | | BC | 5.0 | 0.02 |
| **7b2** | 5 | A1 | 5.3 | 0.04 |
| | | A3 | 5.6 | 0.02 |
| | | B2 | 5.1 | 0.03 |
| | | BC | 5.2 | 0.02 |
| **7c** | 2 | A1 | 6.0 | 0.03 |
| | | A3 | 5.6 | 0.03 |
| | | B21 | 5.0 | 0.04 |
| | | B22 | 5.4 | 0.06 |
| | 10 | A1 | 5.4 | 0.27 |
| | | A2 | 5.1 | 0.10 |
| | | B1 | 5.2 | 0.06 |
| | | B2 | 5.3 | 0.06 |
| | 11 | A1 | 5.6 | 0.05 |
| | | B1 | 4.9 | 0.04 |
| | | B2 | 4.9 | 0.04 |
| | | BC | 4.9 | 0.04 |
| **12a** | 6 | A11 | 6.8 | 0.19 |
| | | A12 | 7.6 | 0.08 |
| | | A3 | 8.2 | 0.08 |
| | | B2 | 8.2 | 0.12 |
| | | BC | 8.5 | 0.07 |
| | 8 | A11 | 7.9 | 0.12 |
| | | A12 | 8.3 | 0.09 |
| | | B21 | 8.6 | 0.08 |
| | | B22 | 8.6 | 0.08 |
| | | BC | 8.7 | 0.08 |
| | 12 | A11 | 7.0 | 0.31 |
| | | A12 | 7.5 | 0.30 |
| | | B2 | 8.2 | 0.14 |
| **12b** | 7 | A11 | 6.5 | - |
| | | A12 | 6.5 | - |
| | | B2 | 6.5 | - |

# Appendix 2 Plant species list for the CDU bushlands study area

The following species were recorded in the study area during the field survey.

| Scientific name | | Common name(s) | Land Unit(s) |
|---|---|---|---|
| **Trees** | | | |
| *Acacia* | *sp.* | Wattle, Acacia | 7a |
| *Acacia* | *auriculiformis* | Black Wattle, Acacia | 7a, 7b1, 7b2, 7c, 12a |
| *Acacia* | *difficilis* | River Wattle, Acacia | 7b1 |
| *Acacia* | *lamprocarpa* | Wattle, Acacia | 7a |
| *Alphitonia* | *excelsa* | Red Ash, Soap tree | 7a |
| *Antiaris* | *toxicaria* | Antiaris | 12a |
| *Bombax* | *ceiba* | Kapok tree, Bombax | 12a |
| *Brachychiton* | *paradoxus* | Red-flowered kurrajong | 7b1 |
| *Buchanania* | *obovata* | Green plum, Wild mango | 7b2, 7c |
| *Canarium* | *australianum* | Canarium | 7b2 |
| *Corymbia* | *polysciada* | Apple gum | 7b1, 7b2, 7c, 12b |
| *Eucalyptus* | *tetrodonta* | Darwin Stringybark | 7a, 7b2 |
| *Ganophyllum* | *falcatum* | Ganophyllum | 12a |
| *Gardenia* | *megasperma* | Native/Wild gardenia | 7b1 |
| *Leucaena* | *leucocephala* | Coffee bush, Lead tree | 7b1, 7c, 12a, 12b |
| *Lophostemon* | *lactifluus* | Red paperbark | 7b1, 7c |
| *Melaleuca* | *viridiflora* | Broad-leaved paperbark | 7b1, 7c |
| *Millettia* | *pinnata* | Pongamia, Millettia | 12a |
| *Myristica* | *sp.* | Myristica | 12a |
| *Petalostigma* | *pubescens* | Quinine tree | 7a |
| *Sterculia* | *quadrifida* | Peanut tree, Sterculia | 12a |
| *Syzygium* | *eucalyptoides* | Syzygium | 7a, 7c |
| *Syzygium* | *suborbiculare* | Red bush apple, Syzygium | 7c |
| *Terminalia* | *ferdinandiana* | Kakadu plum, Billy goat plum | 7a, 7b1, 7b2, 7c |
| *Terminalia* | *microcarpa* | Terminalia | 12a, 12b |
| *Wrightia* | *pubescens* | Wrightia | 12a |
| **Palms/Cycads** | | | |
| *Carpentaria* | *acuminata* | Carpentaria palm | 12a |
| *Cycas* | *armstrongii* | Cycad | 7a, 7b1, 7b2 |
| *Pandanus* | *spiralis* | Pandanus, Screw palm | 7b1, 7b2, 7c, 12b |
| **Shrubs** | | | |
| *Bridelia* | *tomentosa* | Bridelia | 7a, 7b2 |
| *Calytrix* | *exstipulata* | Turkey bush, Fringe-myrtle | 7a |
| *Cathormion* | *umbellatum* | Bean tree, Cathormion | 12b |
| *Exocarpos* | *latifolius* | Native cherry, Exocarpos | 7b2 |
| *Ficus* | *aculeata* | Sandpaper fig | 7a, 7b1, 7b2, 7c |
| *Flueggea* | *virosa* | White Currant, Flueggea | 12a |
| *Jasminum* | *molle* | Jasminum | 7b1 |
| *Micromelum* | *minutum* | Clusterberry, Micromelum | 12a |
| *Murraya* | *koenigii* | Curry tree, Murraya | 12a |
| *Petalostigma* | *quadriloculare* | Witchetty bush | 7a, 7b1 |
| *Planchonia* | *careya* | Cocky apple, Mangaloo | 7b1, 7b2, 7c |
| **Vines** | | | |
| *Ampelocissus* | *acetosa* | Wild grape, Ampelocissus | 7a, 7b1, 7b2, 7c |

| Scientific name | | Common name(s) | Land Unit(s) |
|---|---|---|---|
| *Asparagus* | *racemosus* | Asparagus Vine | 7a, 7b1 |
| *Cayratia* | *trifolia* | Cayratia | 7b1, 7b2, 7c, 12a, 12b |
| *Centrosema* | *sp.* | Centrosema | 7c |
| *Desmodium* | *sp.* | Desmodium | 7c |
| *Dioscorea* | *transversa* | Long yam, Dioscorea | 7b2 |
| *Flemingia* | *parviflora* | Flemingia | 7b2 |
| *Ipomoea* | *sp.* | Ipomoea | 7b1, 12a |
| *Marsdenia* | *sp.* | Marsdenia | 7b2 |
| *Passiflora* | *foetida* | Wild/Stinking passionfruit | 7a, 7c, 12b |
| *Smilax* | *australis* | Smilax | 7a, 7b1, 7b2, 12a, 12b |
| *Stephania* | *japonica* | Stephania | 12a |
| *Tinospora* | *smilacina* | Snake vine, Tinospora | 7a, 7b1 |
| **Forbs** | | | |
| *Commelina* | *sp.* | Commelina | 7b1, 7c |
| *Grewia* | *retusifolia* | Dog's balls, Emu berry | 7b1 |
| *Murdannia* | *sp.* | Murdannia | 7c |
| *Scleria* | *sp.* | Scleria | 7b2 |
| *Spermacoce* | *sp.* | Spermacoce | 7a |
| *Tacca* | *leontopetaloides* | Tacca | 7a, 7b1, 7b2, 7c, 12a, 12b |
| **Grasses/Sedges** | | | |
| *Andropogon* | *gayanus* | Gamba grass | 7a, 7b1, 7b2 |
| *Cyperus* | *sp.* | Cyperus | 7a |
| *Eriachne* | *Sp.* | Wanderrie grass | 7a |
| *Heteropogon* | *triticeus* | Heteropogon | 7c |
| *Ischaemum* | *sp.* | Ischaemum | 7c |
| *Mnesithea* | *rottboellioides* | Northern cane-grass | 7c |
| *Rottboellia* | *cochinchinensis* | Itch grass, Rottboellia | 7b1, 7c |
| *Sorghum* | *sp.* | Sorghum | 12b |
| *Sorghum* | *intrans* | Spear grass, Sorghum | 7a, 7b1, 7c |