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Soil capability assessment for expanding irrigated agriculture in the Dinner Hill focus area, Midlands, Western Australia

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Resource management technical report 406

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Summary

The Midlands groundwater and land assessment is a $4.7 million Water for Food project using Royalties for Regions funding. It is seeking to confirm groundwater availability in focus areas that may form precincts of 2000–3000ha suitable for intensive irrigated horticulture. The Dinner Hill focus area is one of these.

The Dinner Hill focus area covers about 50 200ha to the north-west of Moora and north of Dandaragan, in the Midlands area of Western Australia. This report provides details of the soil-landscapes, land capability and land management units for the Dinner Hill focus area.

We reviewed existing soil-landscape mapping for the area and found that it needed only minor refinement for this study. We also dug and described an additional 117 soil sites in the focus area and sampled nine of these for laboratory analyses.

Two-thirds of the soils of the Dinner Hill focus area are deep sands, usually yellow or red. Ironstone gravelly soils are also common. Because of the sandy nature of the soils, wind erosion is a widespread land management constraint for the Dinner Hill area and ongoing investment is required to manage this, especially for annual horticulture. Water erosion on steeper slopes is also a management constraint.

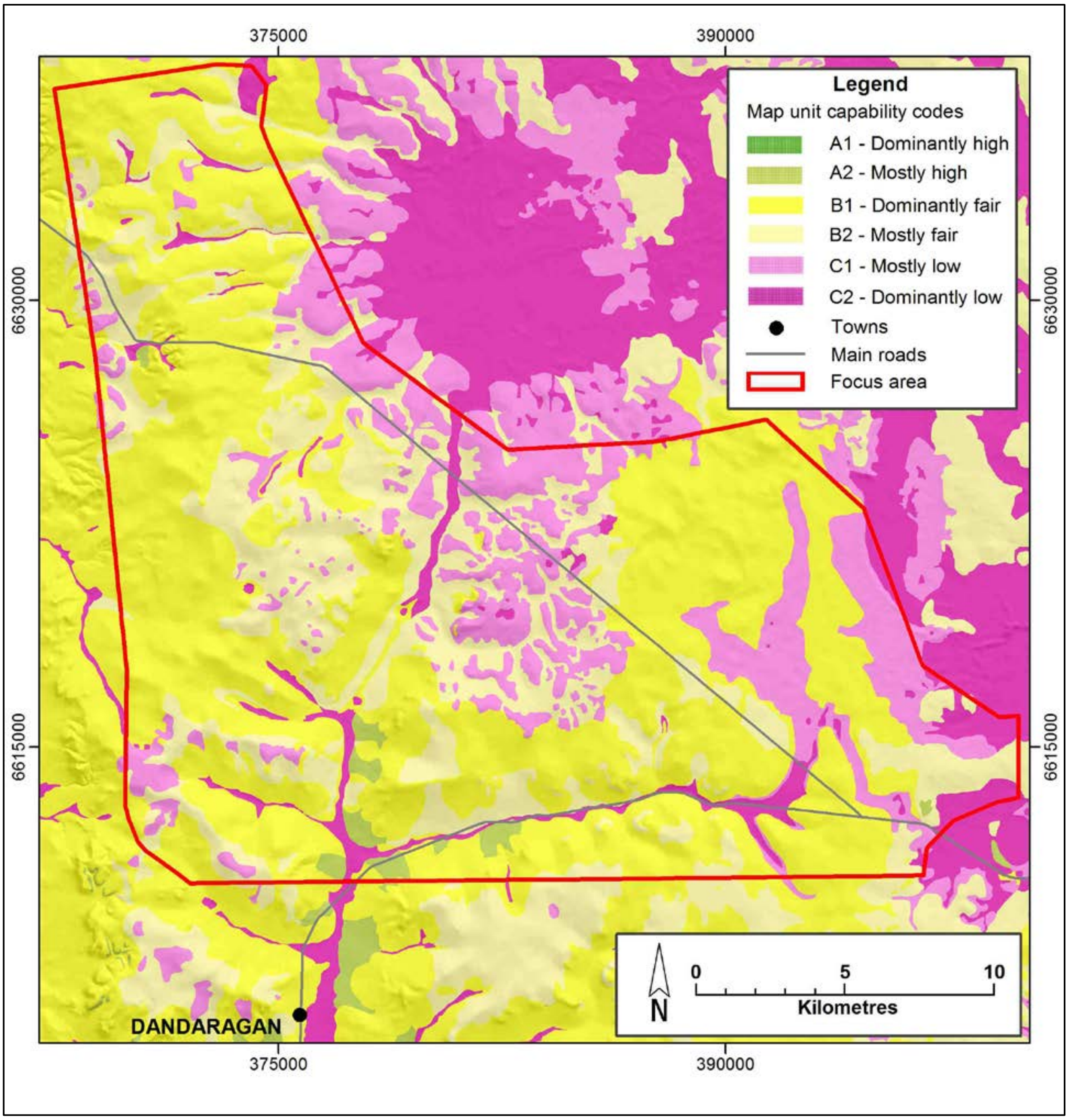
Our analysis showed that if wind erosion risk is managed, most of the soils in the focus area have fair to high capability for annual and perennial horticulture (Figures 1 and 2). Therefore, the limiting biophysical factor for expanding irrigated agriculture in this area is water availability.

This report includes:

- descriptions of geology, geomorphology and the soils
- an outline of the capability of the soil and land for irrigated horticulture
- identification and characterisation of land management units (LMUs).

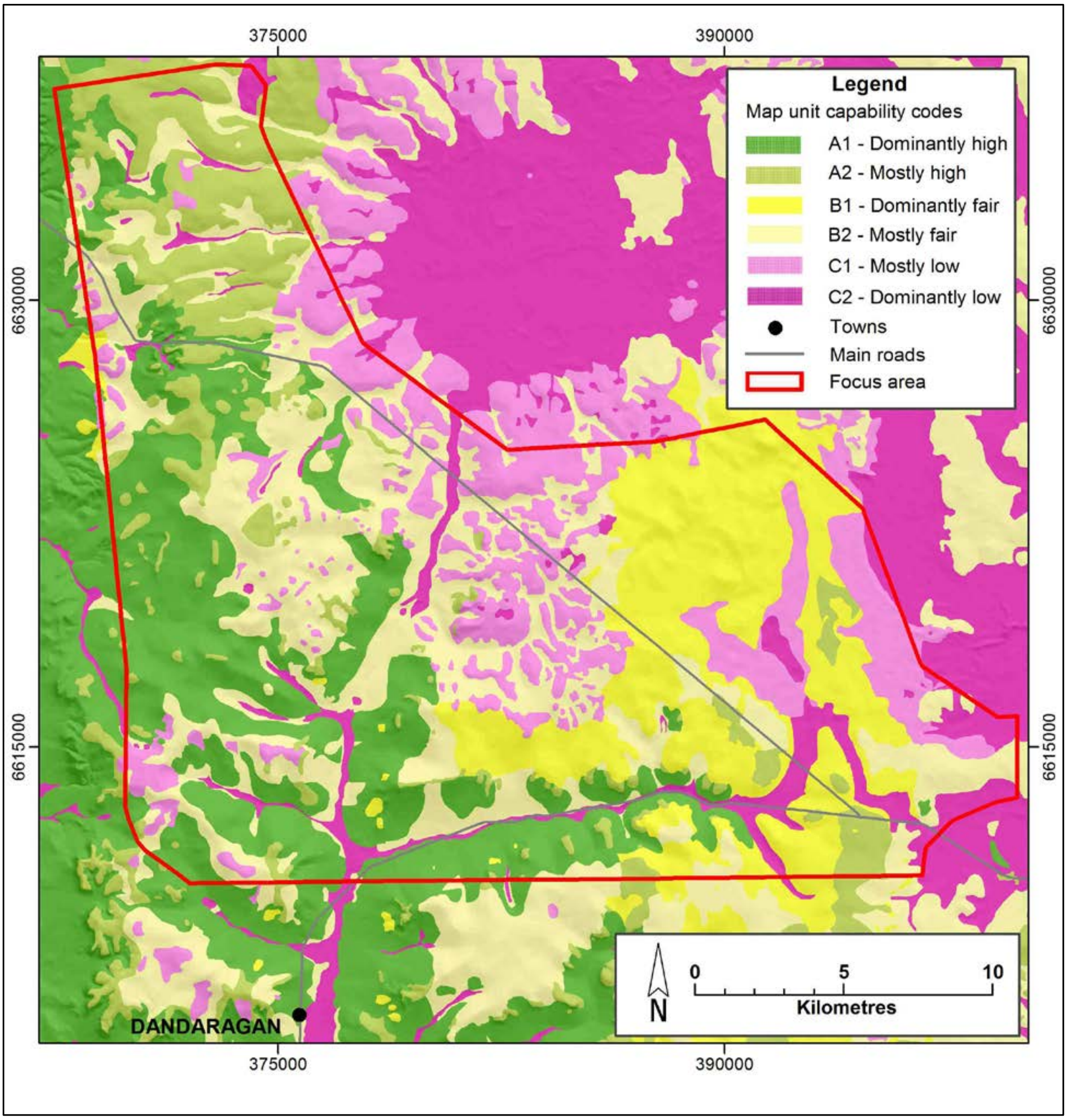
This report should be read in conjunction with companion reports on:

- climate and crop suitability in the Midlands (van Wyk 2019)
- review of the Leederville–Parmelia aquifer hydrogeology (Schafer & Hoare 2018)
- groundwater dependent ecosystems (Department of Water and Environmental Regulation 2018).



Note: The capability assessment assumes that management practices incorporate wind erosion control.

Figure 1 Land capability map for annual horticulture in the Dinner Hill focus area



Note: The capability assessment assumes that management practices incorporate wind erosion control.

Figure 2 Land capability map for perennial horticulture in the Dinner Hill focus area

1 Introduction

The pressures on irrigated agriculture from urban expansion and water availability in the south-west of Western Australia have growers and investors searching for areas of new suitable land with good groundwater resources. There has been development north of Perth at Wanneroo and Gingin, and the Midlands area is viewed as another potential option. The Midlands groundwater and land assessment is a $4.7 million Water for Food project, seeking to confirm groundwater availability in focus areas that may form 2000–3000ha of land suitable for intensive irrigated horticulture between Perth and Geraldton.

Using a multi-criteria analysis process, the groundwater resources of the north Perth Basin were matched with a broad soil capability assessment of the Midlands area to identify potentially suitable locations. Details of this process are in the draft Department of Water (2017a) report. Irwin and Dinner Hill were the two focus areas selected by the project team for closer assessment (Figure 1.1).

This report provides information for the Dinner Hill focus area.

1.1 Midlands Water for Food study area

The Midlands Water for Food study area (often referred to as the West Midlands) is an important agricultural district in the south-west agricultural area of Western Australia (WA). It covers 1.7 million hectares, starting at Wedge Island (about 120 kilometres [km] north of Perth) and ending halfway between Dongara and Geraldton. It extends east to Mingenew and Moora. It includes most of the shires of Dandaragan, Coorow, Carnamah, Three Springs, and Irwin, as well as portions of the Moora and Mingenew shires (Figure 1.1). The eastern boundary largely follows the eastern edge of the Perth Sedimentary Basin.

Historically, broadacre agriculture — mainly cereal cropping and pastures for sheep and cattle — has been the dominant land use in the Midlands area. Now it is recognised for its current and potential future production of horticultural crops. Large portions are Crown reserves, partly reflecting the significant biodiversity values in the area and partly representing the low capability for agriculture of areas such as the coastal dunes.

Annual vegetable crops, mostly carrots, onions, potatoes and leafy vegetables, and tree crops including citrus, nuts and olives currently dominate horticulture in the Midlands.

Extractive industries have been a major component of the area's economy, particularly mineral sands near Eneabba and, increasingly, mining of high quality coastal lime sands for amelioration of acidifying agricultural soils.

All industries are significantly dependent on groundwater, managed by the Department of Water and Environmental Regulation through licensing and setting allocation limits for the aquifers in groundwater subareas (Figure 1.2).

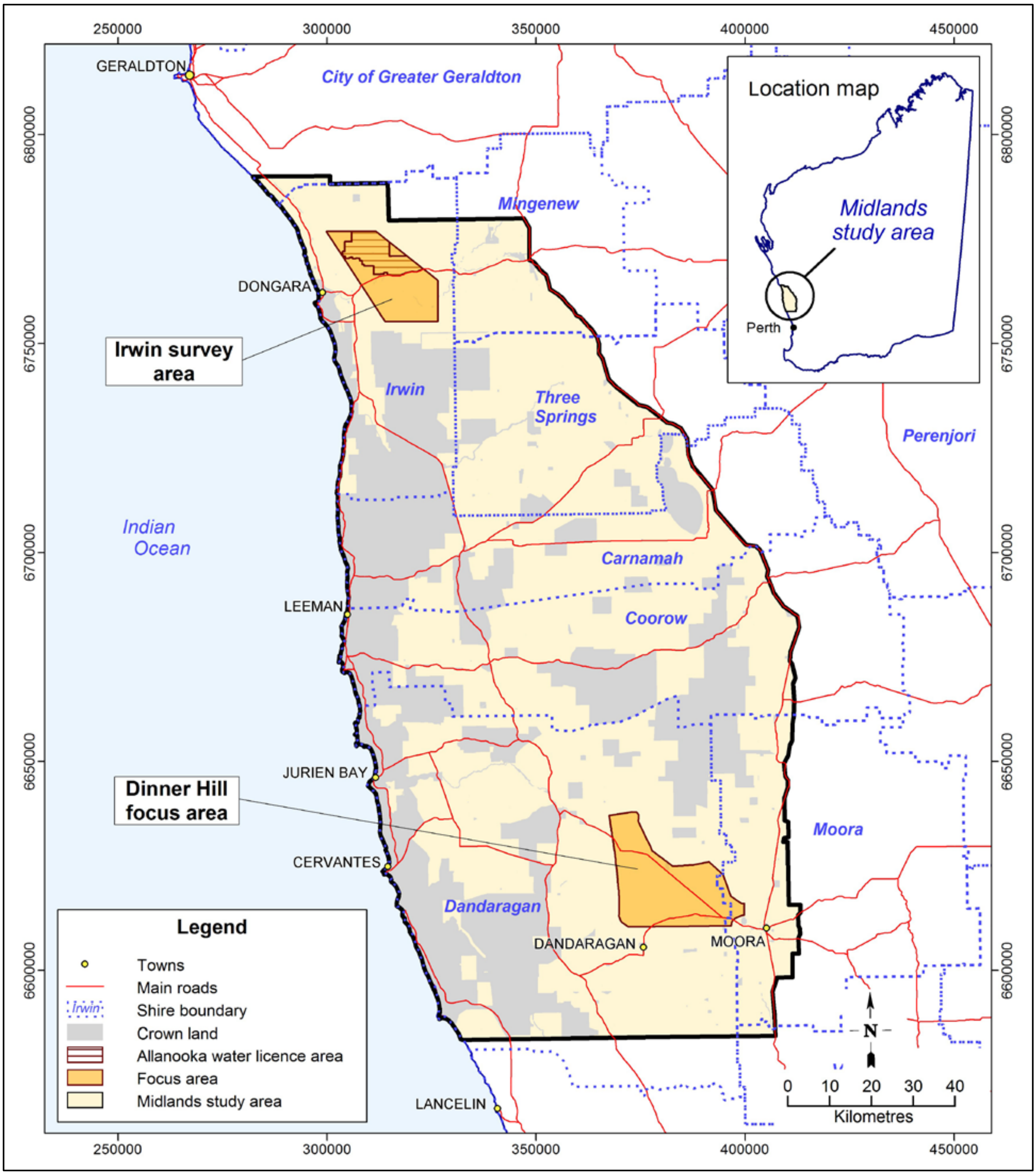


Figure 1.1 Midlands study area showing locations of the Dinner Hill and Irwin areas

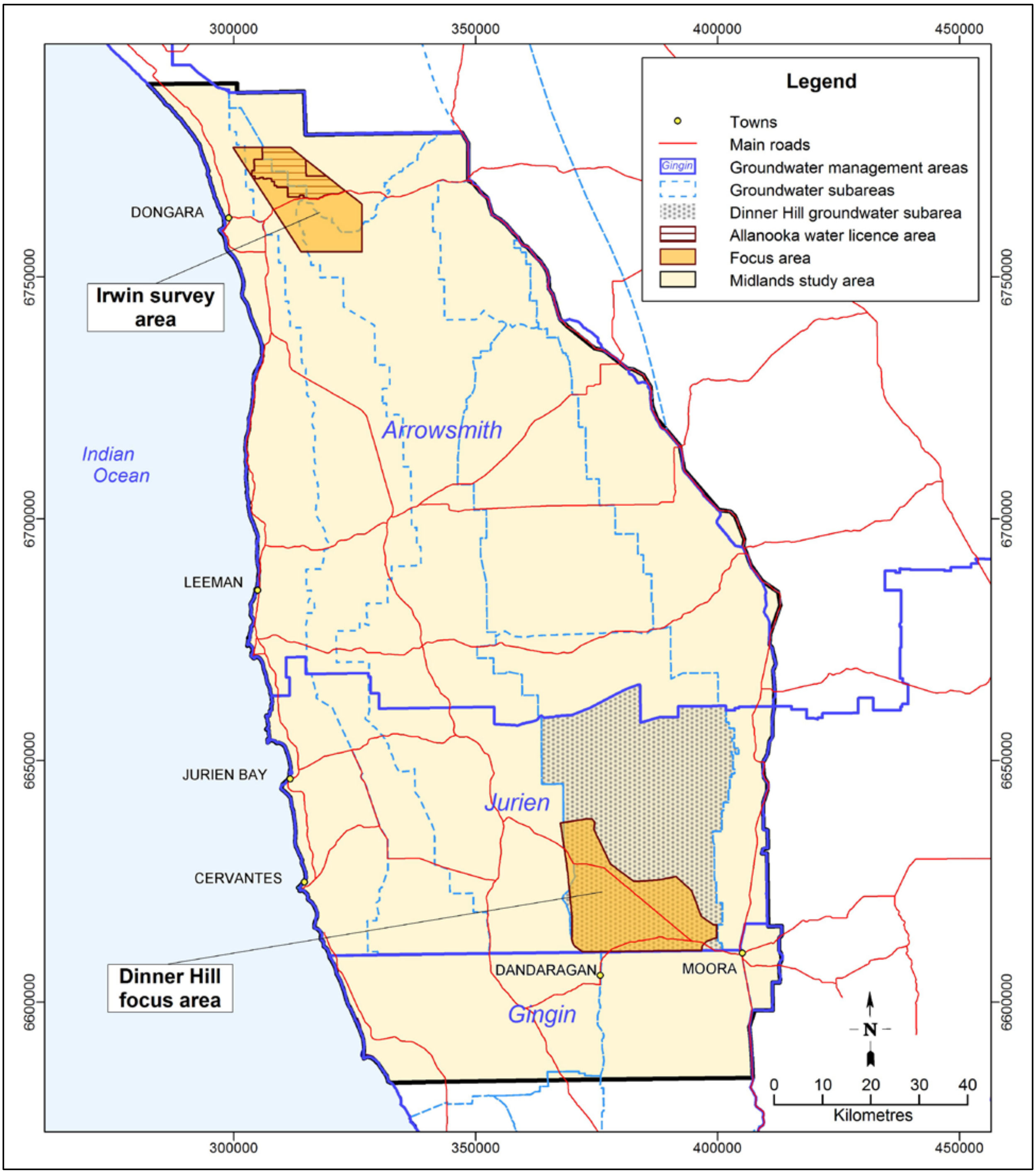


Figure 1.2 Location of the Dinner Hill groundwater areas and subareas within the Midlands study area

1.2 Dinner Hill focus area

The Dinner Hill focus area covers about 50 200ha to the north-west of Moora and north of Dandaragan, sitting on the Dandaragan Plateau soil-landscape zone (Figure 1.3). It covers the southern part of the Dinner Hill groundwater subarea (Department of Water 2014). However, the results in this report should not be extended across the whole of the Dinner Hill groundwater subarea because the focus area is very different from the remainder.

The focus area covers a slightly larger area than originally identified by the Department of Water (2017a), to more broadly represent the land and dominant soil types around Dandaragan.

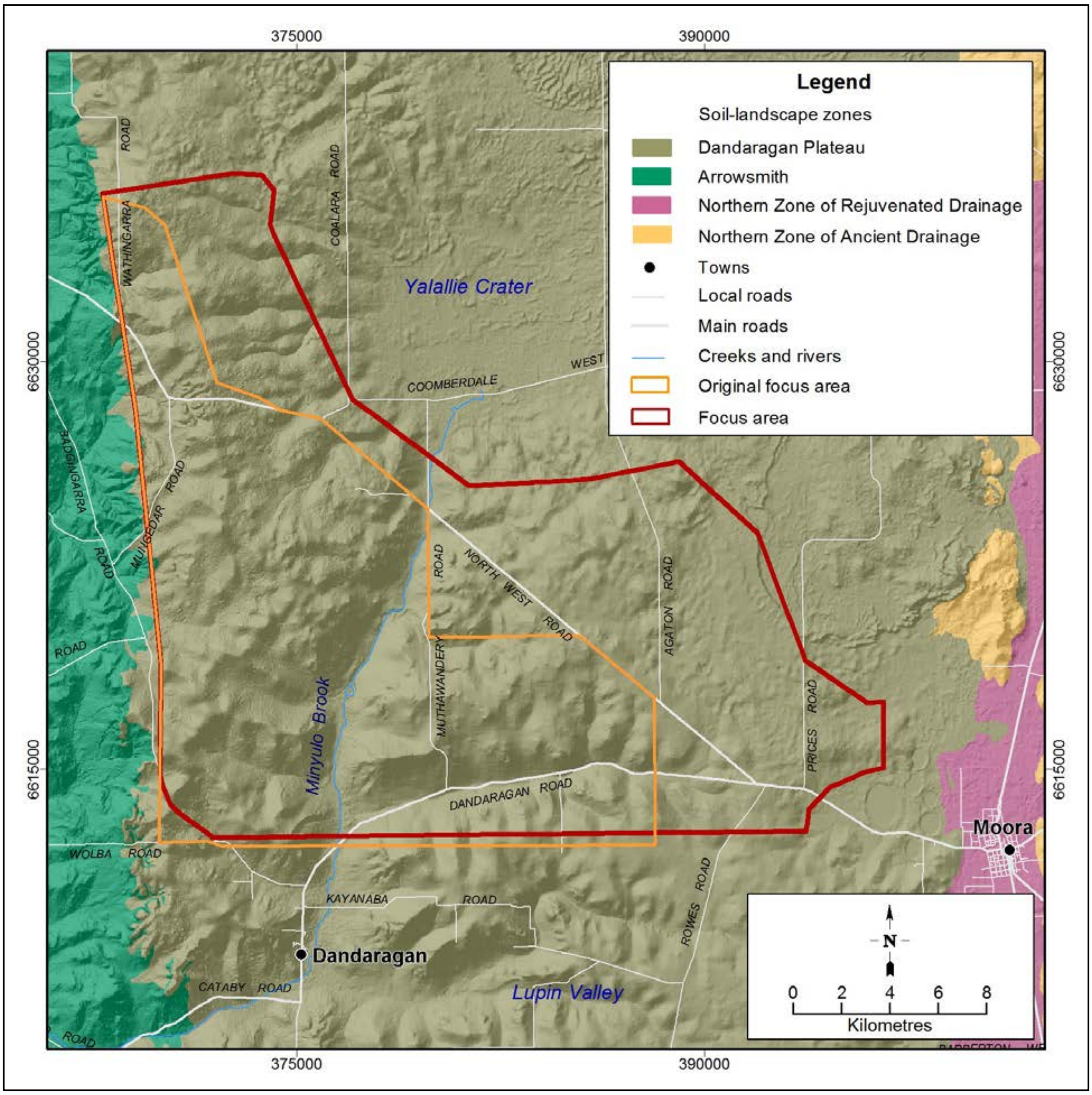


Figure 1.3 Dinner Hill focus area

This report accompanies a regional crop and climate suitability analysis (van Wyk 2019). This information also complements the draft groundwater resource prospectivity mapping undertaken by Baddock and Johnson (2018), which identifies potential areas for groundwater use.

This report provides:

- descriptions of geology, geomorphology and the soils of the Dinner Hill focus area
- an outline of the capability of the soil and land in the focus area for irrigated horticulture
- identification and characterisation of land management units (LMUs).

Some of the figures included in this report have been extended south of the focus area to include similar land and soils around Dandaragan.

2 Focus area assessment

An existing (unpublished) land resource survey covers the focus area, allowing us to quickly identify areas needing review. The original survey is *Dandaragan land resources survey* (Griffin n.d.) at a scale of 1:100 000.

In this review, we used geo-located, remotely sensed data (e.g. digital elevation models and gamma radiometrics) that were not available when original surveys were undertaken. Combining these tools with existing information and new field survey observations, we corrected inconsistencies in original mapping and attribution. The scale is suited for the general location of more intensive land uses, such as horticulture.

Additional data themes used in mapping included:

- existing site locations (DPIRD's Soil Profile Database)
- existing soil-landscape mapping and attribution (DPIRD's Map Unit Database)
- aerial imagery.

2.1 Field survey procedure

We conducted the field survey for this study in May and November 2016. The survey involved checking the existing map boundaries describing soil profiles and collecting samples for physical and chemical analyses.

We chose sites for profile descriptions to validate the distribution within the existing map unit information, with an emphasis on map units identified as having potential for irrigated horticulture (Figure 2.1).

We examined 117 soil profiles using a combination of hand digging and auger boring. We described soils using the methods and terminology in the *Australian soil and land survey field handbook* (National Committee on Soil and Terrain 2009). Field data that we recorded routinely included:

- soil texture
- soil colour (Munsell Color Company 1975)
- soil pH (Raupach & Tucker 1959)
- landform features
- slope percentage
- depth to restrictive layer or watertable.

We examined the soil and parent material to about 15m at seven sites, with mechanical deep-drilling equipment used for groundwater assessment. We sampled and electronically logged (EM39 and gamma) three sites to aid in characterisation.

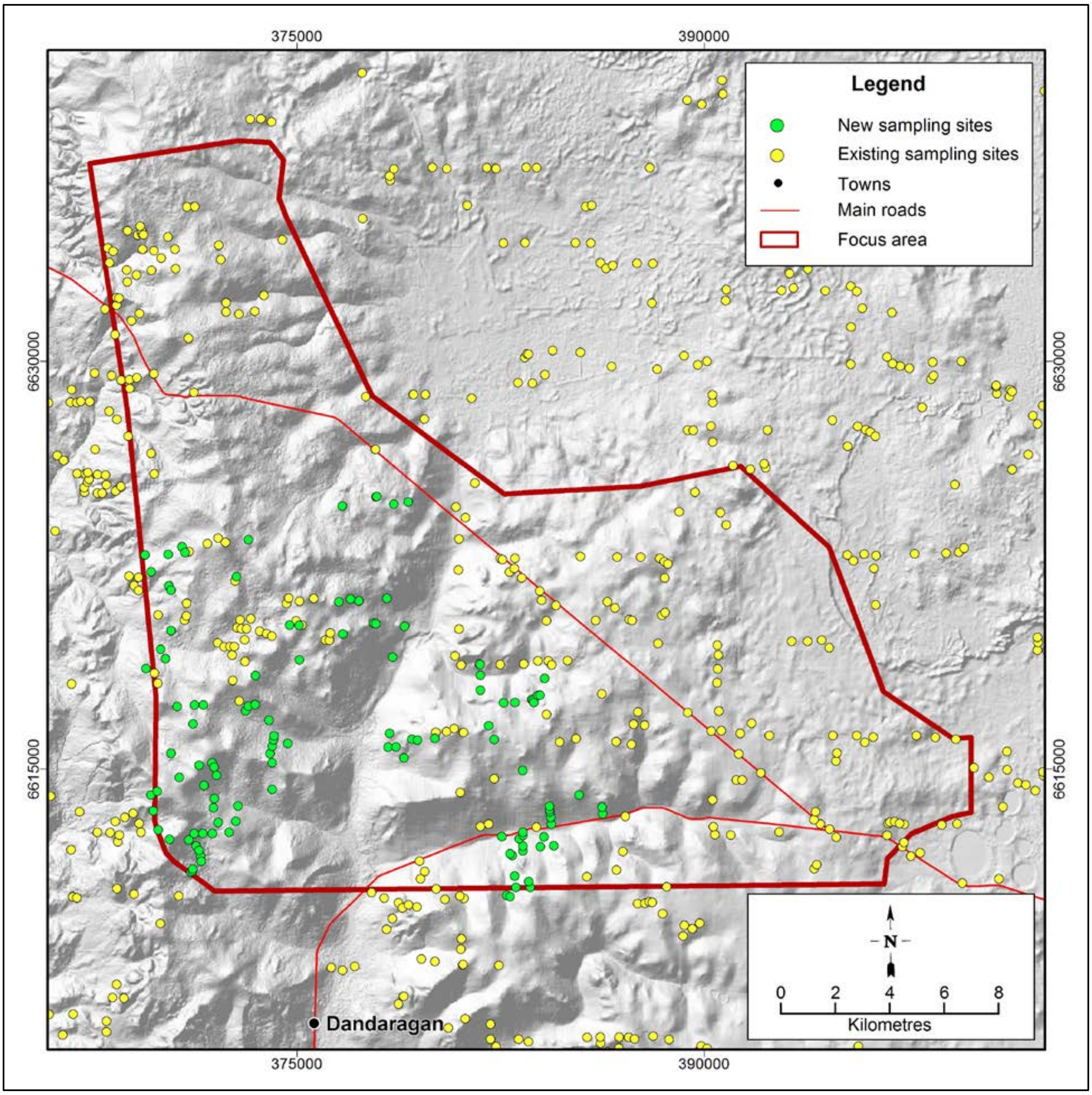


Figure 2.1 Soil sample sites in the Dinner Hill focus area

We used some chemistry data previously collected in the Dinner Hill area, (dating mostly from Churchward 1970) and we sampled an additional nine sites for analysis for this study. We submitted 190 fine-earth (<2mm) samples to CSBP for selected analyses (using methodologies outlined in Rayment & Higginson 2011):

- clay, silt and sand (%)
- calcium carbonate, $CaCO_3$ (%)
- electrical conductivity (EC1:5)
- pH (1:5, water and calcium chloride [$CaCl_2$])
- organic carbon (OC) Walkley and Black method
- nitrogen — total of each, ammonium (NH_4) and nitrate (NO_3)
- phosphorus (bicarbonate [HCO_3] extractable)
- potassium (HCO_3 extractable)

- iron, copper, zinc and manganese (extractable in DTPA [diethylene triamine pentaacetic acid] method)
- sulfur (extractable in potassium chloride, KCl)
- boron (extractable in $CaCl_2$)
- exchangeable cations (calcium, potassium, magnesium, sodium and aluminium).

We sent another 12 samples to ChemCentre for mineralogy, particularly to identify the most likely clay minerals present in the parent material.

Figure 2.2 shows where chemistry data is now available in the Dinner Hill focus area.

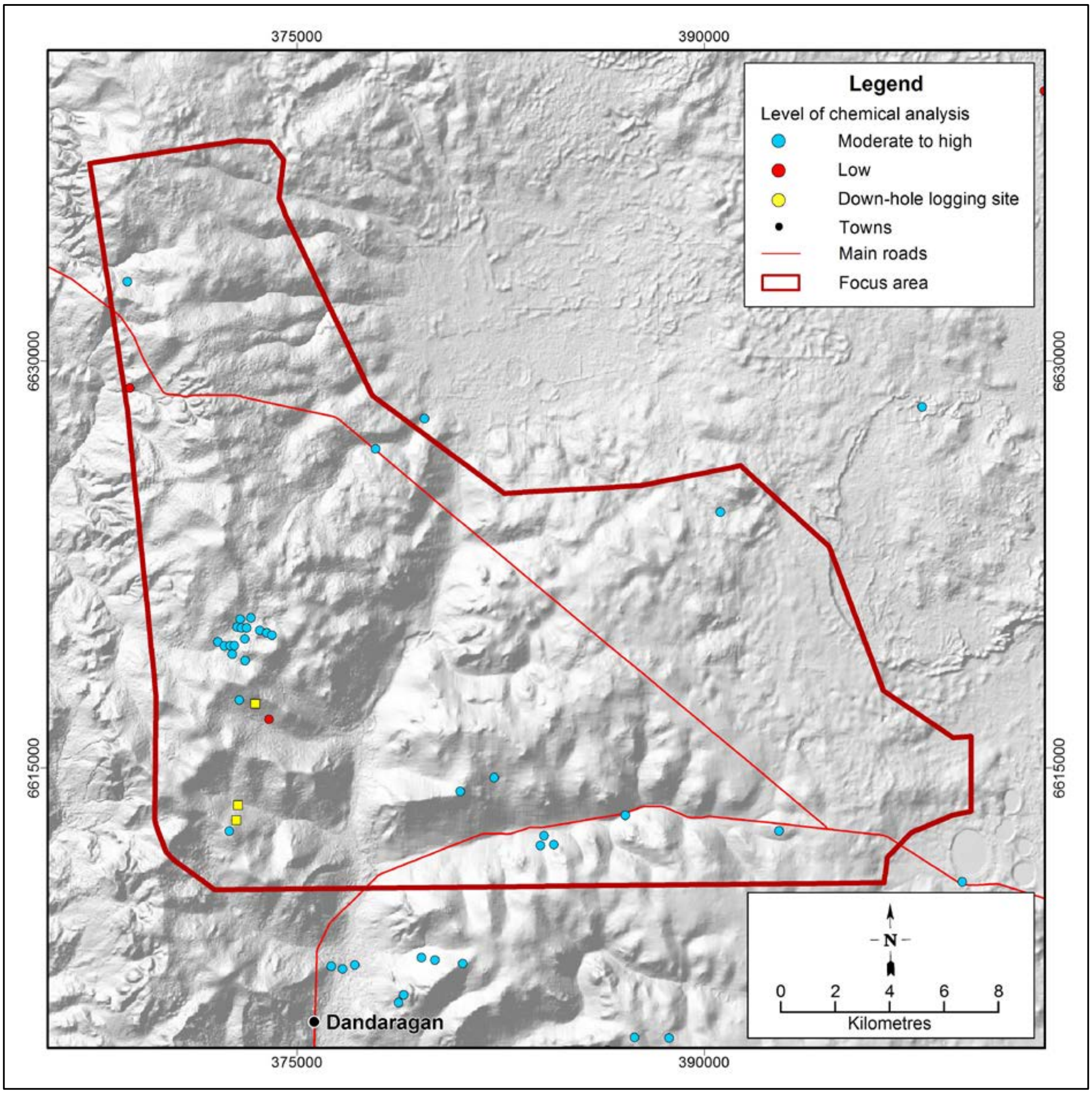


Figure 2.2 Soil sites with chemistry data and down-hole logging in the Dinner Hill focus area

2.2 Soil profile and map unit data analyses

After completing site descriptions, we entered all field data into DPIRD's Soil Profile Database. We used soil profile morphology to classify each site according to the Western Australian Soil Groups (Schoknecht & Pathan 2013) and in some cases, the Australian Soil Classification (Isbell & National Committee on Soil and Terrain 2016).

We used this information to review the map unit boundaries and the proportional attribution of qualified WA Soil Groups against each of the soil-landscape units in DPIRD's Map Unit Database (Schoknecht et al. 2004).

2.3 Land capability analysis and land qualities

Land capability refers to the ability of the land to support a particular land use. It takes into account the productive potential of the land as well as potential on-site and off-site effects. Land with a high capability for a particular agricultural land use will be capable of sustaining high yields without causing degradation to soil, land, and air or water resources. Failing to manage land according to its capability risks degradation and can lead to a decline in natural ecosystem values, potentially with long-term impacts on agricultural productivity, supporting industries and communities.

Land qualities are used to determine capability. Wells and King (1989) define land qualities as 'the attributes of land that influence its capability for a specified use'. These qualities can relate specifically to the soil, such as pH, or to the landform, such as flood hazard; or they can relate to both soil and landform characteristics, such as wind erosion hazard (van Gool et al. 2005).

Land capability assessment also considers the specific agricultural requirements of the soil, such as soil depth, soil water-holding capacity and the risk of degradation associated with establishing various agricultural activities. A big part of the capability assessment is defining the land use, and including the consideration of management practices.

Annual horticulture production is an intensive agricultural industry. It requires demanding operational management and the effects on land and water resources can be significant. This means that future horticultural development needs to be closely aligned to the capability of each area's land units (a soil type in a landform position) to avoid adverse impacts on land and water resources.

2.3.1 Land capability ratings

We based land capability ratings for perennial and annual horticulture on the methodology described by van Gool et al. (2005). For both horticultural land uses, we assigned a rating from 1 to 5 (Table 2.1).

The ratings tables we used to determine capability for annual and perennial horticulture are modified versions of those presented by van Gool et al. (2005). The land qualities used and the ratings tables for the two horticultural land uses are presented in Appendix A (Tables A1.1, A2.1 and A2.2).

Table 2.1 Land capability classes

Capability class	General description
1 – Very high	Very few physical limitations present and easily overcome. Risk of land degradation is negligible.
2 – High	Minor physical limitations affecting productive land use or risk of degradation. Limitations can be overcome by careful planning.
3 – Fair	Moderate physical limitations significantly affecting productive land use and/or risk of degradation. Careful planning and conservation measures are required.
4 – Low	High degree of physical limitation not easily overcome by standard development techniques and/or resulting in high risk of degradation. Extensive conservation measures required.
5 – Very low	Severe limitations. Use is usually prohibitive in terms of development costs or the associated risk of degradation.

Some modifications we adopted from Tille et al. (2013). These bring in land qualities that are particularly relevant to the sandy soils that dominate the focus area, including soil water storage within the top 50cm of the profile and inherent soil fertility.

Small variations in the grain sizes and clay content of these sands affect the storage of added water and nutrients in the root zone. The lower the storage capacity of the sands, the more difficult the combined management of irrigation and fertiliser applications to maintain production becomes. This is especially a consideration during the warmer summer months when there are fewer margins for error.

Without careful management, water and nutrients are likely to move below the root zone of the crops on these sands. This is a wasteful use of limited water resources and it can lead to poor crop performance, without the extra expense of additional irrigation and fertiliser applications to maintain yields. It is also likely to contribute to off-site problems such as eutrophication of waterways.

The ratings tables used in this report also adopted the modifications of Tille et al. (2013) in relation to wind erosion hazard. The ratings tables in this report assume that erosion control measures are part of these land uses. Examples include keeping the soil surface moist when it is bare and disturbed, and using wind breaks. Such control measures are an important part of managing horticultural production on sandy soils in this dry, windy environment.

A land quality we developed for this study is ‘irrigation salinity hazard’, which assesses the potential for salinity to develop under regular irrigation. It takes into account factors such as profile permeability and existing salt storage, slope gradients and landforms. We describe our methodology for assessing irrigation salinity hazard in Griffin et al., 2019, Appendix A4.

2.3.2 Land capability mapping

We assessed land capability ratings for each of the soil and landform combinations assigned to the map units in DPIRDs Map Unit Database (Table A3.1 in Appendix A3 provides an example of this). Because of the range of combinations, most map units have a range of rating classes proportionally assigned. To present capability on a map, a capability code (Table 2.2) based on these proportions is assigned to each map unit. Appendix A3 provides an example of proportional allocation.

Table 2.2 Map unit capability codes

Code	Map unit capability description
A1	Dominantly high capability (>70% of the map unit is Class 1 or 2)
A2	Mostly high capability (50–70% of the map unit is Class 1 or 2)
B1	Dominantly fair capability (70% of the map unit is Class 1 or 2 or 3)
B2	Mostly fair capability (50–70% of the map unit is Class 1 or 2 or 3)
C1	Mostly low capability (50–70% of the map unit is Class 4 or 5)
C2	Dominantly low capability (>70% of the map unit is Class 4 or 5)

Source: van Gool et al. (2005)

3 Geology

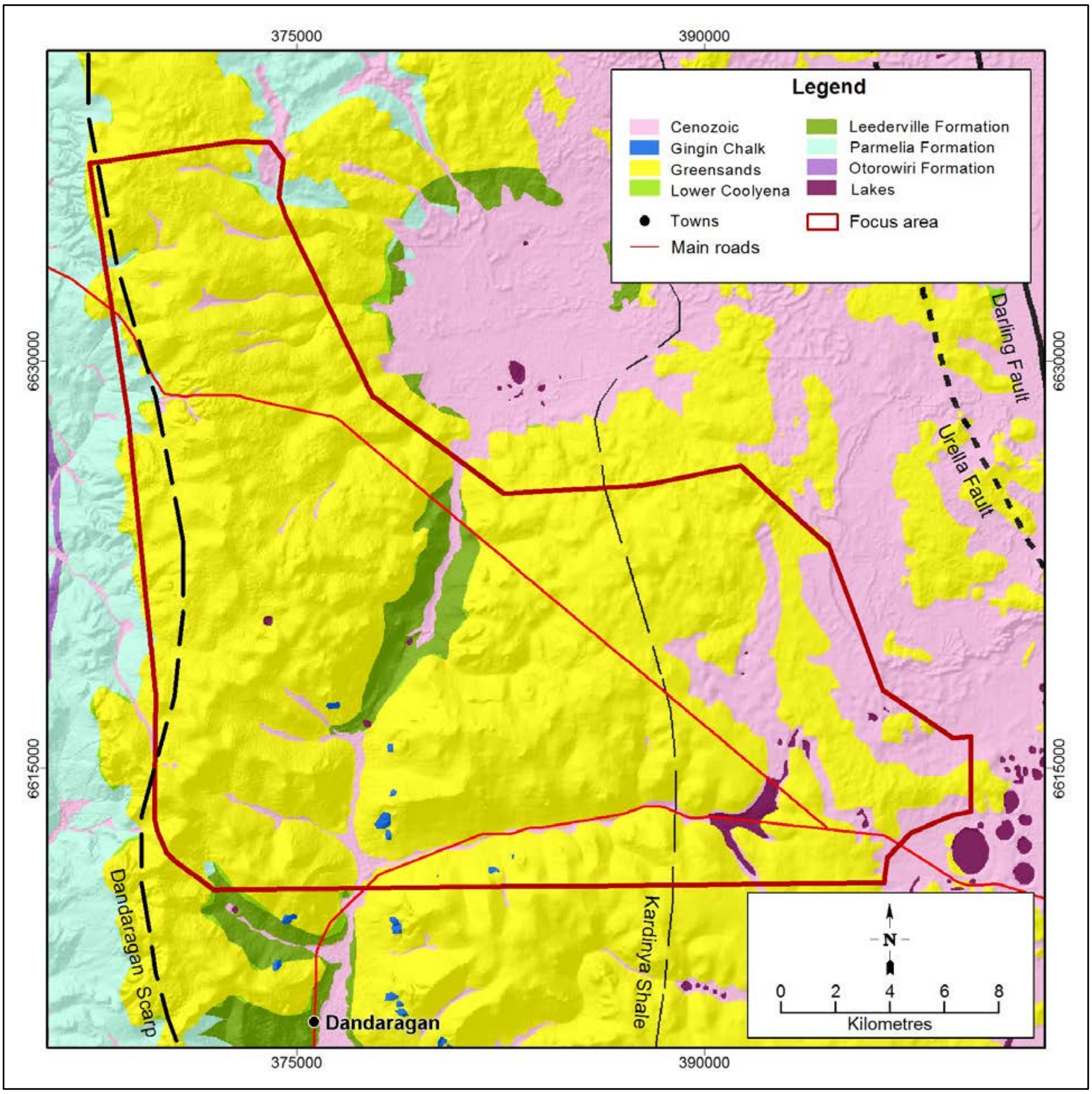
Weathered material of the Northern Perth Basin blankets most of the Midlands study area. The basin is comprised of terrestrial Mesozoic sedimentary rocks with significant groundwater resources. For a detailed account of the geology of the Midlands, see Department of Water (2017b). The stratigraphy of the sediments most relevant to the focus area and surrounds is in Table 3.1. Figure 3.1 illustrates their suggested surface expression. Figure 3.2 is a west–east stratigraphic cross-section illustrating the dip of the major sediments.

Table 3.1 Stratigraphy of Upper Mesozoic sediments of the Dinner Hill focus area

Group	Formation	Stratigraphy	Maximum thickness (m)	Lithology	Deposition location
Coolyena Group	Lancelin Formation	Poison Hill Greensand	41	Sandstone, siltstone, clay and glauconitic	Near-shore shallow marine
			18	Chalk, sandy and glauconitic	Shallow marine
		Gingin Chalk	102	Sandstone, glauconitic	Shallow marine
Unconformity					
	Osborne Formation	Mirrabooka Member	40	Sandstone, glauconitic, with siltstone and shale	Shallow marine
		Kardinya Shale Member	235	Siltstone and shale, minor sandstone	Marine
		Henley Sandstone Member	48	Sandstone, minor siltstone and claystone	Shallow marine
Unconformity					
Warnbro Group	Leederville Formation	Pinjar Member	182	Sandstone, siltstone and shale	Marine to non-marine
		Wanneroo Member	390	Sandstone, with lesser siltstone and shale	Non-marine to marine
		Mariginiup Member	205	Sandstone, siltstone and shale	Marine
Unconformity					
Parmelia Group	Undifferentiated Parmelia Formation		~300	Sandstone, siltstone and shale	Fluvial to lacustrine
	Otorowiri Formation		102	Shale and siltstone, minor sandstone	Lacustrine

Source: Department of Water (2017b)

The late Cretaceous Coolyena group dominates the topography and soil of the focus area. This group consists mainly of marine sediments featuring two greensands units — an upper unit called the Poison Hill Greensands and a lower unit called the Molecap Greensands. Sandwiched between these two units is the Gingin Chalk. As the chalk occurs consistently in the mid-slopes of the major drainage lines (Figure 3.1), the surface extent of the upper greensands unit (i.e. Poison Hill Greensands) is likely to be the most extensive of the greensands. The surface presence of the lower unit (Molecap Greensands) is inferred to be minor.



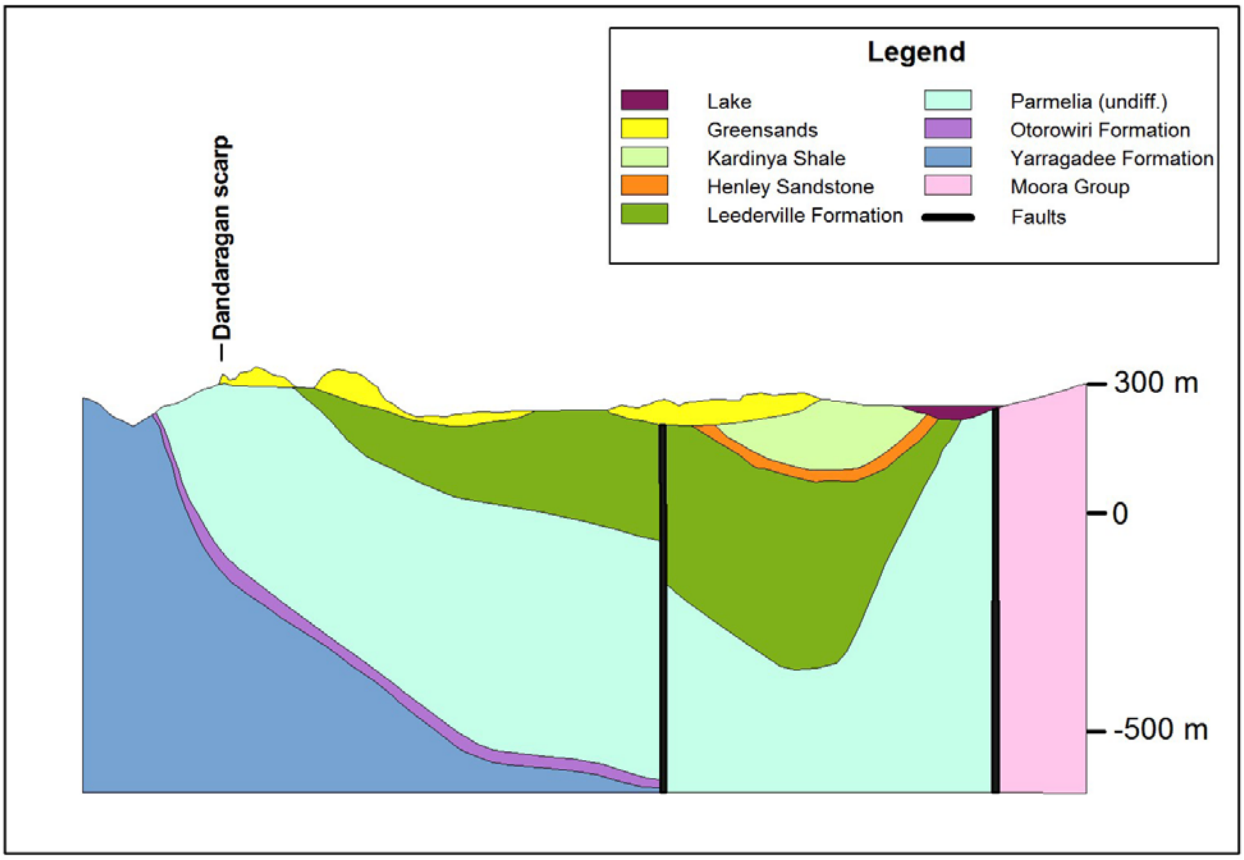
Source: Department of Water (2017b), with Cenozoic and Gingin Chalk from DPIRD soil-landscape mapping

Figure 3.1 Surface expressions of sediments

In the north-west of the focus area, the greensands overlie the Parmelia Formation. In the west, the greensands overlie the Leederville Formation. In the east, they overlie the Osborne Formation (and particularly over the Kardinya Shale member in that formation; Figure 3.2).

The incision by the Minyulo Brook reveals the Leederville and Parmelia formations. However, there is little evidence that the Kardinya Shale is exposed; it being overlain by either the greensands or the unconsolidated Cenozoic sediments.

In the focus area, the Dandaragan Scarp is prominent and commonly capped by strong duricrust or ferruginous sandstone. Once thought to be the Dandaragan Sandstone (Briese 1979), this material is now considered part of the Parmelia Formation. Its ferruginous nature may relate to enrichment from the weathering of the overlying greensands.



Source: Department of Water (2017b), based on west–east Moora bore transect which approximately aligns along the southern boundary of the focus area

Figure 3.2 Stratigraphic cross-section

3.1 Yallalie meteorite impact crater

Since the deposition of the Cretaceous Coolyena group, there has been little tectonic movement in the region (Figure 3.2), although Playford et al. (1976) suggested there may have been minor preferential settlement against the Darling Fault.

The most significant recent geological event relevant to the focus area is the Yallalie meteorite impact crater, which has distorted Mesozoic sediments. The crater shows up as a distinctive, rounded depression on Coomberdale West Road, between

Muthawandery and Agaton roads, north-west of Moora (Figure 1.3). Inferences from sediment suggest this occurred around the early Pleistocene (Department of Water 2017b, Economo 1991, Dentith et al. 1999).

3.2 Hydrogeology

The aquifers in the Dinner Hill area are complex. Department of Water (2017b) contains the detailed hydrogeology of the North Perth Basin. To better conceptualise the groundwater in the Dinner Hill area for this project, Schafer and Hoare (2018) reviewed the Leederville–Parmelia aquifer hydrogeology.

Historically, farm water supply in the Dandaragan area was sourced from soaks and shallow (unconfined) groundwater. Recharge areas tend to be at the hilltops of yellow and pale sands, and the soaks are in naturally damp areas in mid to lower slopes. The Minyulo Brook (Figure 1.3) has historically yielded water all year round from these unconfined sources for most of their reaches. However, regional groundwater seepage comes from the Leederville aquifer in the lower portions.

4 Geomorphology and soil-landscapes

4.1 Geomorphology

The focus area is located on an upland geomorphological feature known as the Dandaragan Plateau. The western boundary of the focus area runs close to the Dandaragan Scarp, which rises 50–100m above the dissected sedimentary terrain of the Arrowsmith Soil-landscape Zone.

The highest point in the focus area is in the north-west along the Dandaragan Scarp at Bald Hill, sitting at 377m above sea level. From the scarp, the Dandaragan Plateau surface drops gently eastwards. The south-east corner of the focus area near Lake Dalaroo is the lowest point, sitting about 206m above sea level.

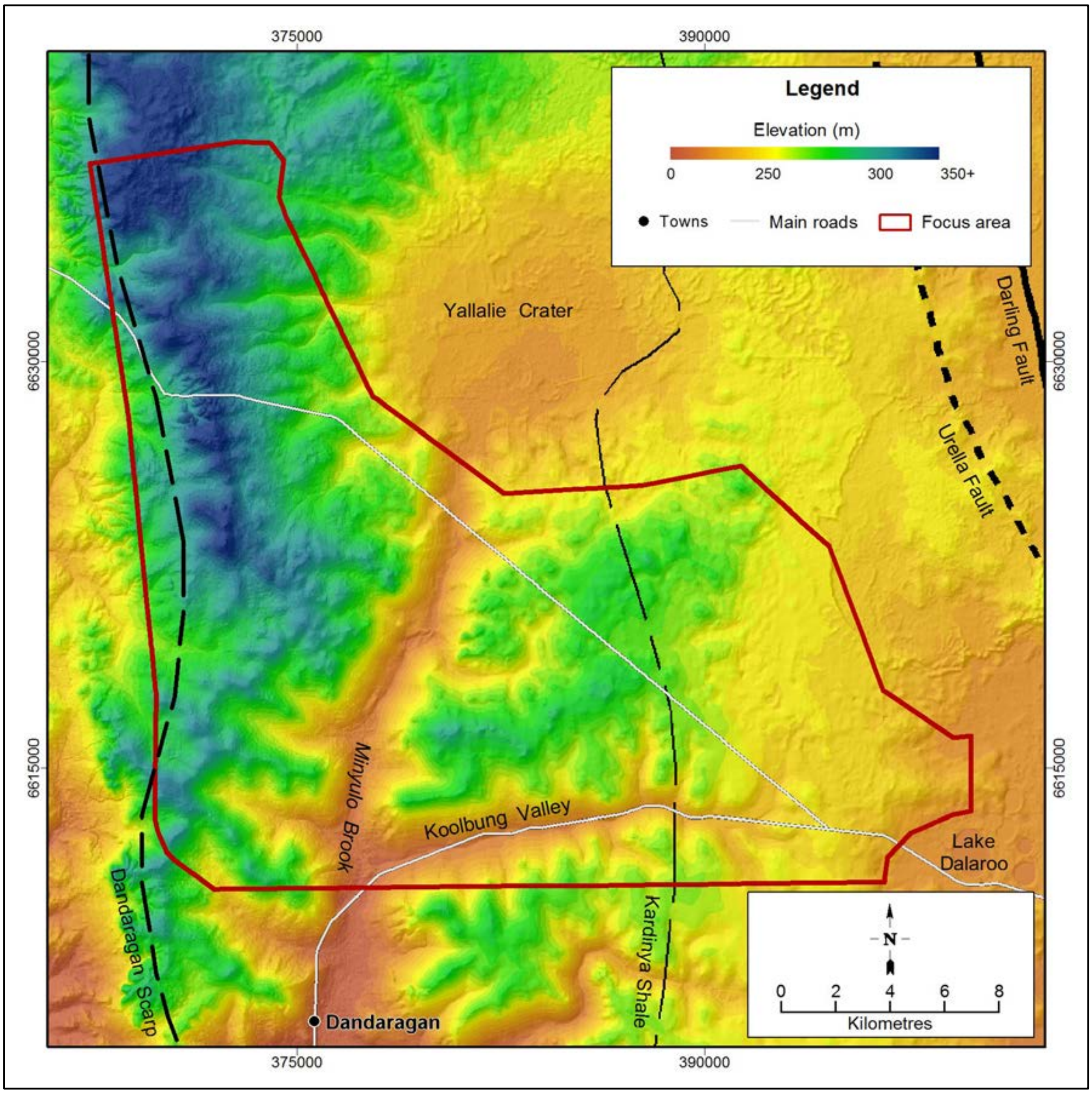


Figure 4.1 Elevation of the Dinner Hill focus area on shaded relief

The focus area is atypical of the Dandaragan Plateau in that it is dominated by hillslopes rather than plateau remnants or sandplains. It owes its nature to the Minyulo Brook, which has etched deeply into the highly erodible greensands. Churchward (1970) described this as ‘erosional modification of a lateritised landscape’. Minyulo Brook meets the Yallalie Crater at the north-east boundary of the focus area and divides the higher land to the west associated with the Dandaragan Scarp and the gentle slopes to the east. The east–west oriented Koolbung Valley at the southern border meets the brook.

In keeping with the rest of the Dandaragan Plateau, the very eastern portion of the focus area is subdued and drains eastward into the Moore River. The upper reaches of the westward-draining Minyulo subcatchment tributaries also have low gradients. At their headwaters many have ancient lake deposits; most likely dating from the Tertiary. In the Dandaragan area, the western limit of these lakes is roughly the western (subsurface) extent of the Kardinya Shale (Figure 4.1).

Sitting directly to the north and east of the focus area, the Yallalie Crater has a significant influence on the landforms of the plateau. Its outer edges are characterised by converging (centripetal) drainage with distinct interfluvial ridges (Figure 1.3). The morphology of these drainages is subdued relative to the southern discharge into the Minyulo Brook and indicates that the Minyulo Brook ‘captured’ a previously internally drained basin.

4.2 Soil-landscape mapping

The Dinner Hill focus area lies almost entirely in the Dandaragan Plateau Soil-landscape Zone (222) (Figure 1.3). To the west of the Dandaragan Scarp, the dissected sedimentary terrain belongs in the Arrowsmith Soil-landscape Zone (224). Only 24ha of the Arrowsmith Zone sits within the focus area.

Within the focus area, the Dandaragan Plateau Zone is divided into five soil-landscape systems, which are summarised in Table 4.1 and illustrated in Figure 4.2. The small part of the Arrowsmith Zone within the focus area only includes one soil-landscape system, Boothendarra. Cross-sections in Figure 4.3 and Figure 4.4 illustrate the topographic relationships of the systems of the Dandaragan Plateau Zone.

Within the Dandaragan Plateau Zone, three distinct soil-landscapes systems in the focus area are on the greensands lithology: Dandaragan, Rowes and Capitella. Their degree of stripping is what separates them.

The hillslope-dominated Dandaragan System (222Da) covers more than half of the focus area, extending about 5km east from the Dandaragan Scarp in the north of the focus area, and further inland up the Koolbung Valley in the south. It has the greatest relief and is the most stripped portion of the greensands (Figure 4.3).

While very few of the Dandaragan System hillslopes exceed gradients of 10%, more than a quarter of the system has gradients of 5–10% and a third has gradients of 3–5%. A distinguishing feature of these slopes is the uniformity of the soils down the slope. Quite often deep sands (at least 1m deep), with relatively consistent grain size and clay content, extend from the top of the slope to the edge of the valley floor, with the main variation being the colour of the sand (grading from yellow to brown and red). Less common soils in this system are ironstone gravels, often found higher in the landscape, as well as sandy and loamy earths and some sandy duplex soils.

The greensands in the east of the focus area are mainly mapped as the Rowes System (222Rw) which forms a broad sandplain. Churchward (1970) interpreted this as a residual lateritised landscape. This is a relatively flat landscape with few slopes exceeding gradients of 3%.

Yellow deep sands cover over half of the Rowes System, with other soils including sandy gravels, Pale deep sands and Yellow sandy earths. These sands tend to have lower clay content than those found on the Dandaragan System.

The Capitella System (222Cp) is a gently undulating landscape with lateritic ridges and sandy colluvial slopes is the third system formed mostly on greensands and found in the south-east of the focus area. Very few slopes exceed 3% and almost all of the system is well drained. About half the system is Yellow deep sands, but they tend to have a lower clay content and coarser grain size than those in the Rowes System. Almost a quarter of this system has Pale deep sands, with sandy duplex soils and Yellow sandy earths also present.

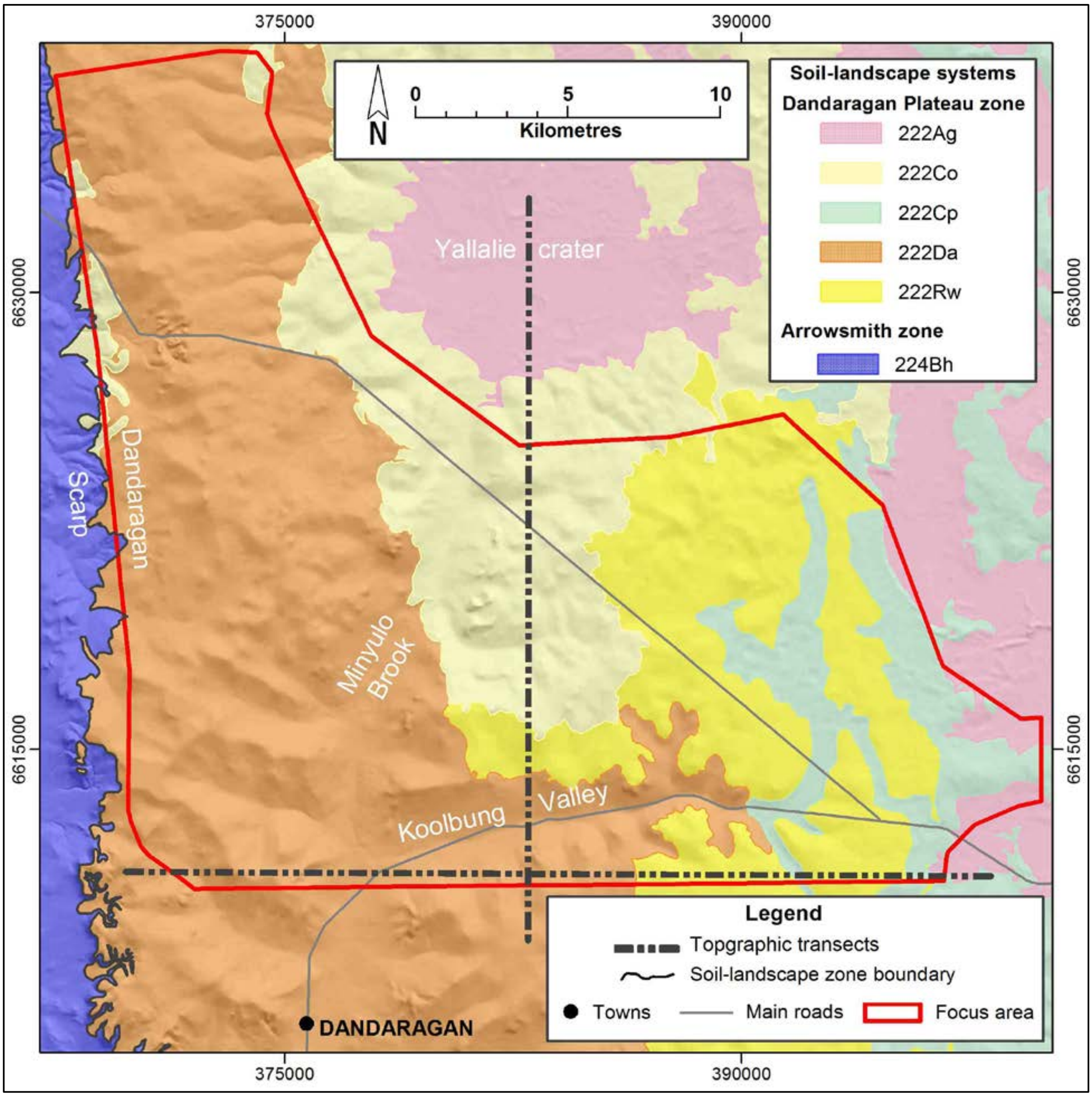
The Coalara System (222Co) occupies the northern-central portion of the focus area. It is also a gently undulating landscape with lateritic ridges and sandy colluvial slopes, and about a third of the system has slope gradients of 3–10% (Figure 4.4). Although Figure 3.1 shows greensands underlie the area, we suspect the Coalara System here has formed directly on the Parmelia Formation. The soils are mainly a mix of Yellow deep sands (with similar qualities to those in the Capitella System), Pale deep sands and sandy gravels.

Lastly, the Agaton System (222Ag) is on the unconsolidated sediments (alluvium, sand sheets and low dunes) found on the eastern edge of the focus area. This system extends towards Moora, dominates the Yallalie Crater, but only has a small occurrence in the focus area.

About one-third of the Agaton System is mapped as poorly drained flats and depressions in the focus area. Another third is well-drained flats and the remaining third is low sandy rises. Poor quality Yellow deep sands are the most common soil, along with Pale deep sands and minor areas of Semi-wet soils, sandy duplex soils and shallow sands.

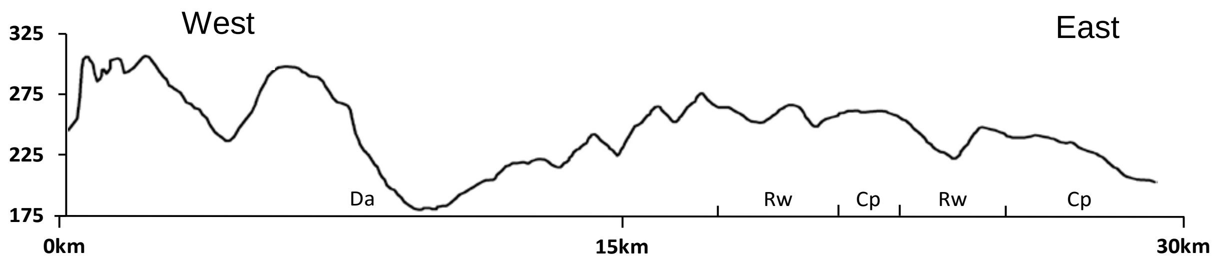
Table 4.1 Soil-landscape systems in the Dinner Hill focus area

Soil-landscape zone	Soil-landscape system	Code	Area (ha)	Proportion of focus area (%)	Description
Dandaragan Plateau (222)	Agaton	222Ag	640	1	Gently undulating to level plains with dunefields, playa lakes and salt lakes on alluvial and sandy aeolian deposits in the eastern Dandaragan Plateau. Soils are mainly Yellow and Pale deep sands, minor sandy duplexes and shallow sands over clay, iron or carbonate pans, Saline wet soil and Salt lake soil. Vegetation is shrubland, banksia woodland and halophytic vegetation.
	Coalara	222Co	8 370	17	Partially dissected plateau with crests, slopes and sandy valley plains on weathered Cretaceous sandstones in the western margin of the Dandaragan Plateau. Soils are mainly Pale and Yellow deep sands, sandy gravels and sand over gravel. Vegetation is mainly heath and scrub heath with banksia and *Eucalyptus todtiana* open low woodland.
	Capitella	222Cp	3 930	8	Subdued, stripped lateritic plateau, undulating to gently undulating low rises with gently undulating plain including dunes on weathered Cretaceous sediments plus alluvial and aeolian deposits in the Dandaragan Plateau, east of Dandaragan. Soils are mainly Pale and Yellow deep sands, sandy gravels and sand over gravel, with heath and woodland vegetation.
	Dandaragan	222Da	26 430	53	Subdued, dissected lateritic plateau, undulating low hills and rises with narrow alluvial plain in larger drainage lines on colluvium from Cretaceous marine sandstones. Found in the southern Dandaragan Plateau, from Dandaragan to Gingin. Main soils are Red, Brown and Yellow deep sands, sandy gravels, minor sandy or loamy earths, duplexes and clays with Marri woodlands and shrublands vegetation.
	Rowes	222Rw	10 830	22	Subdued, partly dissected lateritic plateau, gently undulating plains and gently undulating to undulating rises on weathered sediments (mainly Osborne and Lancelin formations) in the southern Dandaragan Plateau, east of Dandaragan. Soils are mainly Yellow and Pale sands, sandy gravels and some Gravelly pale deep sands and sandy earths. Vegetation is *Banksia prionotes* low woodland and species-rich heath.
Arrowsmith (224)	Boothendarra	224Bh	24	<1	Subdued, stripped lateritic plateau with undulating rises to gently undulating plains on laterite, siltstone and sandstone in the west Midlands area. Sandy duplexes, Pale deep sand, sandy and loamy gravels and minor clays. Vegetation is wandoo woodland, *Eucalyptus todtiana* and banksia low open woodland, scrub heath and some mallee.



Note: Topographic transect cross-sections are depicted in Figure 4.3 and Figure 4.4.

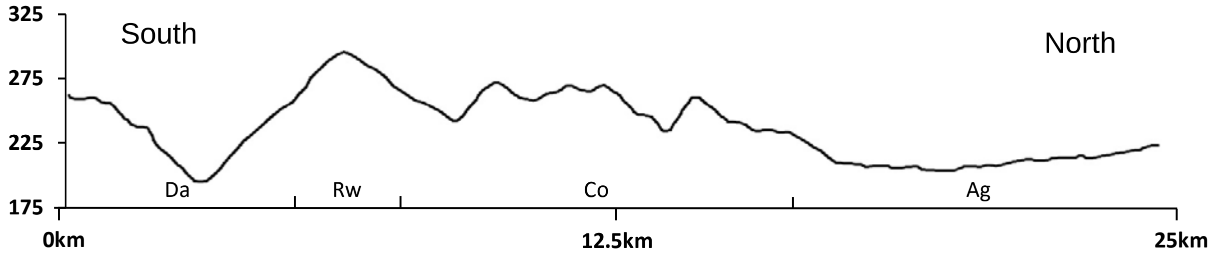
Figure 4.2 Soil-landscape systems of the Dinner Hill focus area



Da = Dandaragan, Rw = Rowes, Cp = Capitella soil-landscape systems

Note: Transect location is in Figure 4.1.

Figure 4.3 West–east transect along southern boundary of the Dinner Hill area



Da = Dandaragan, Rw = Rowes, Co = Coalara, Ag = Agaton soil-landscape systems

Note: Transect location is in Figure 4.1.

Figure 4.4 South–north transect from Koolbung Valley to Yallalie Crater in the Dinner Hill focus area

Each system is subdivided into soil-landscape subsystems and phases, called soil-landscape map units Table B1 in Appendix B provides a summary description of each map unit. The soil-landscape mapping and more-detailed map unit descriptions for the focus area are available online at NRInfo <https://www.agric.wa.gov.au/resource-assessment/nrinfo-western-australia>.

The existing soil-landscape mapping remains too coarse to delineate individual soil types on a scale suitable for farm management and irrigation planning. We recognise their presence by an estimated proportion of soils related to landscape positions found within each map unit. These proportions form part of the map unit description available on the NRInfo website with a table showing the percentage area of each qualified WA Soil Group in each landscape position. Table A3.1 in Appendix A presents the example of the soil proportion for the map unit 222Rw_3a.

4.3 Main soils

While we have identified 44 different WA Soil Groups in the Dinner Hill focus area, just 11 soil groups cover around 90% of the total area (Table 4.2).

Over two-thirds of the focus area is covered by deep sands, which Schoknecht and Pathan (2013) define as having a maximum soil texture of a clayey sand (<10% clay) in the top 80cm of the profile. In the focus area, about half of these are Yellow deep sands. Red and Brown deep sands are also present, mostly in the west; while Pale deep sands and Gravelly pale deep sands tend to become more common in the east.

Ironstone gravelly soils — mainly Deep sandy gravel, Duplex sandy gravel and Shallow gravel — make up about half of the remaining area; and the next most common grouping, the sandy earths, make up less than 5% of the total area.

Table 4.2 Main soils of the Dinner Hill focus area

WA Soil Group	Approximate area (ha)	Area (%)
Yellow deep sand	17 700	35
Red deep sand	5 500	11
Pale deep sand	4 600	9
Brown deep sand	4 200	8
Deep sandy gravel	3 000	6
Gravelly pale deep sand	2 900	6
Shallow gravel	2 000	4
Duplex sandy gravel	2 000	4
Yellow sandy earth	950	2
Red shallow sand	780	2
Red sandy earth	760	2

Note: WA Soil Groups covering less than 2% of the focus area are excluded.

Many of the map units in the focus area have a relatively low variability of soils. This is especially the case for sandplains and simple hillslopes where deep sands are common. Soils tend to be more diverse on hillcrests, breakaways and pediment slopes where gravels or heavier soils are more common.

The WA Soil Groups differentiate the deep sands on soil colour, and the presence of ironstone gravel in the subsoil in the case of the Gravelly pale deep sand. As well as variations in colour and gravel content, these deep sands have differing levels of clay content, sand grain size and changes down the profile.

These differences are often quite significant and form the basis of the WA Soil Group qualifiers (van Gool et al 2005). The native vegetation and the agricultural performance of the sands reflect the variation. Relatively small differences in clay content can have significant impacts on the sand's ability to retain moisture and nutrients. Within the focus area, the Yellow deep sands in particular show a fair degree of variation.

As a general guide, sands with 5–10% clay have been qualified as 'good sands', sands with around 5% clay have been qualified has 'fair sands', and sands with very low clay content have been qualified as 'poor sands'. The good sands are most common in the west on the Dandaragan System, while the poor sands are most common in the east on the Coalara, Capitella and Agaton systems. In the Rowes System, fair sands are most common, with a fairy equal split between good and poor sands.

4.4 Subsoil nature of deep sands

The soil texture of the subsurface of deep sands will influence water infiltration down the profile. Because variable drainage of the deep sands could significantly influence the fate of excess irrigation water, we drilled a small number of additional sites to about 10m to understand more about the nature of the Red deep sand in particular. Soil textures and chemical analyses of all these sites are in Appendix C.

We also measured three sites for down-hole electromagnetic conductivity and gamma signals to get a clearer picture of the apparent conductivity (salinity levels) of the soil matrix at greater depth (Figure 2.2). Appendix D shows the results of these measurements.

We found that the Red deep sands are the weathering product of the glauconite-rich greensands sediments. Weathering of the greensands liberates iron oxides that coat the quartz. The Brown, Yellow and Pale deep sands generally result from the iron leaching from the Red deep sands.

Site WM0232 is an example of Red deep sand that has glauconite at about 6m (Appendix E). At this site, the overlying sands tend to have more clay than other red or brown sands on this sediment. Site WM0230 also has clay at depth, but there was no sign of glauconite within the top 10m.

Overall, we found these sands to be very deep (>5m), with medium to fine particle sizes which changed little down the profile. This indicates that there should be good drainage for these ‘heavier’ deep sands.

The most conspicuously bleached sands are the areas of Pale deep sand (e.g. site WM0229) at the bottom of a hillslope where perched water has accumulated. Therefore, some areas of Pale deep sand on mid to lower slopes may also be an indicator of perched water, as was identified at site WM0231.

Soils on hillcrests are mostly Yellow or Pale deep sands. These can also be very deep (legacy site P 0446, Appendix E).

Gravel is uncommon in the Red and Brown deep sand soil types in the Dandaragan area. This is in contrast to the Pale deep sands and to a lesser degree, the Yellow deep sands of colluvial slopes, which may have abundant amounts of gravel within the top metre.

5 Land capability for horticulture

As described in Section 2.3, land capability refers to the ability of the land to support a particular land use. It takes into account the productive potential of the land as well as potential on-site and off-site effects.

The assessment assumed management practices that incorporate wind erosion control are in place. Control of wind erosion is an expected part of normal management of any irrigated agriculture enterprise.

The capability assessment shows that, if wind erosion is managed, most of the focus area has soil-landscapes capable of supporting annual and perennial horticulture. Map units that mainly have a low capability for annual and perennial horticulture cover only about 20% of the area (Table 5.1, Figure 5.1).

Table 5.1 Area of annual and perennial horticulture capability codes in the Dinner Hill focus area

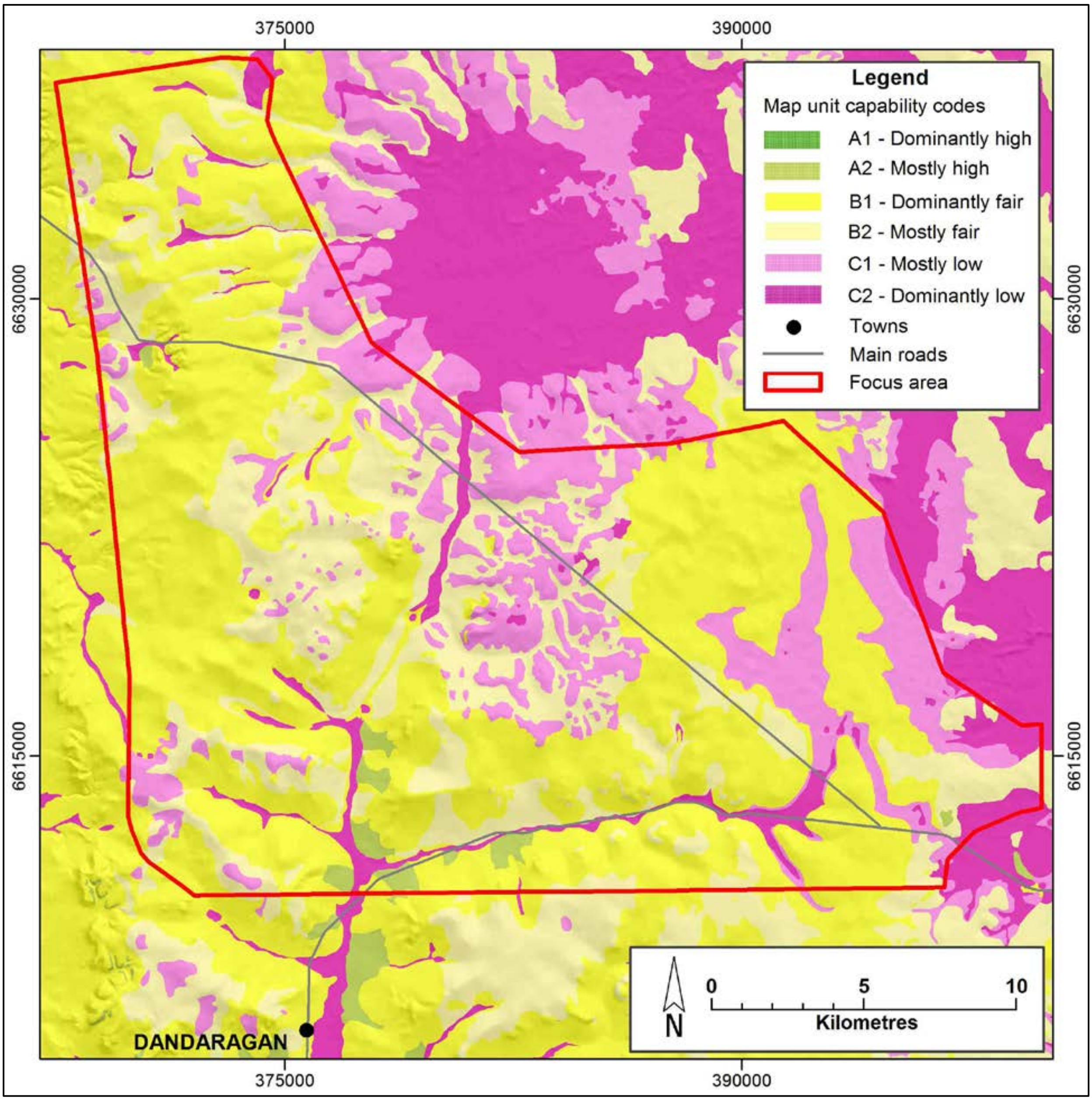
	Annual horticulture		Perennial horticulture	
Capability code	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
A1	0	0	11 483	23
A2	584	1	6 058	12
B1	26 687	53	9 071	18
B2	12 653	25	13 305	26
C1	7 969	6	7 301	15
C2	2 339	5	3 014	6

The land capability assessment for annual and perennial horticulture across the focus area uses the map unit capability codes in Table 2.2 (and repeated below in Table 5.2 to show the relationship to the capability mapping opposite).

Table 5.2 Map unit capability codes

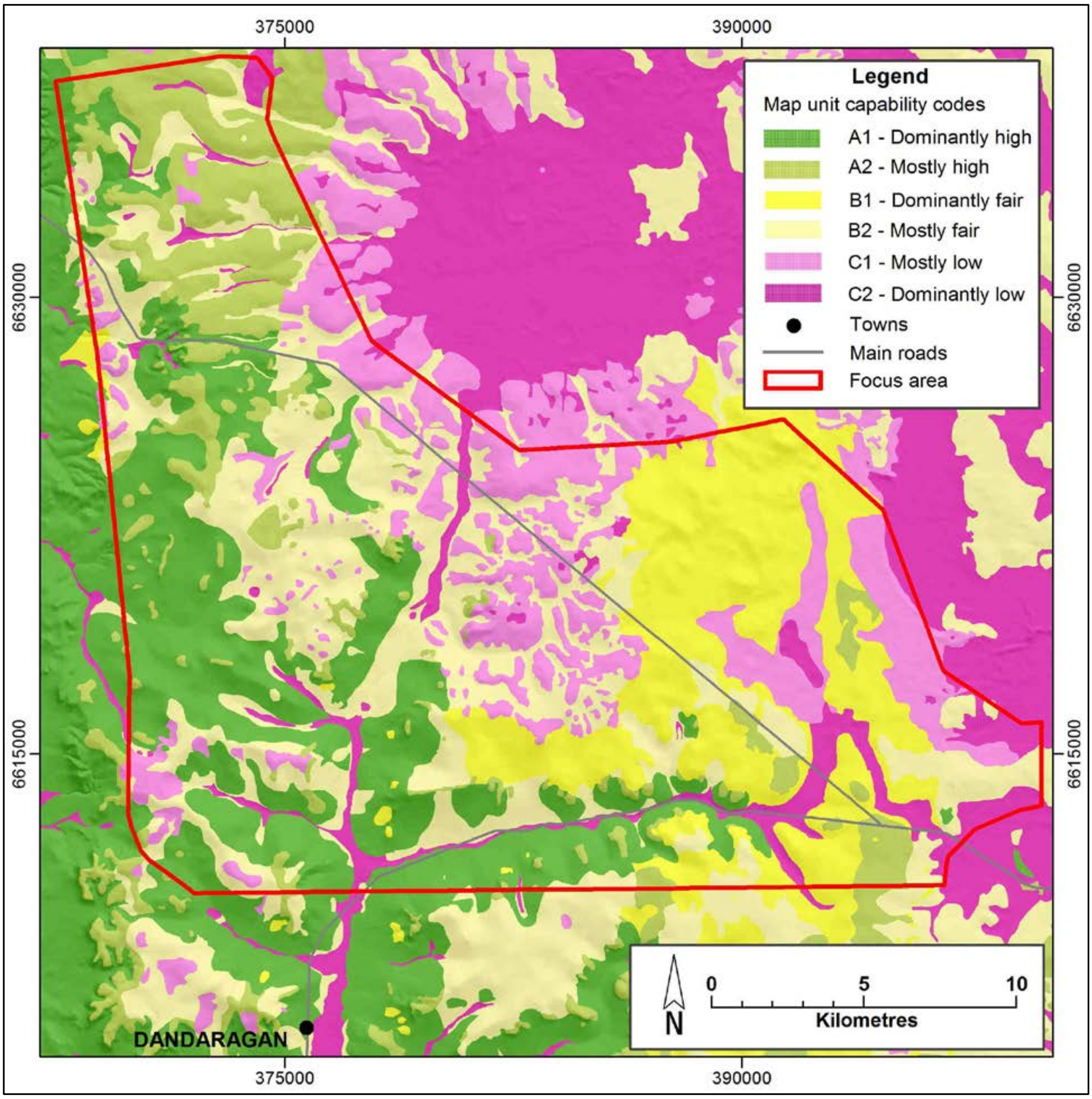
Code	Map unit capability description
A1	Dominantly high capability (>70% of the map unit is Class 1 or 2)
A2	Mostly high capability (50–70% of the map unit is Class 1 or 2)
B1	Dominantly fair capability (70% of the map unit is Class 1 or 2 or 3)
B2	Mostly fair capability (50–70% of the map unit is Class 1 or 2 or 3)
C1	Mostly low capability (50–70% of the map unit is Class 4 or 5)
C2	Dominantly low capability (>70% of the map unit is Class 4 or 5)

Source: van Gool et al. (2005)



Note: The capability assessment assumes that management practices incorporate wind erosion control.

Figure 5.1 Land capability map for annual horticulture in the Dinner Hill focus area



Note: The capability assessment assumes that management practices incorporate wind erosion control.

Figure 5.2 Land capability map for perennial horticulture in the Dinner Hill focus area

There are differences between the land uses: about a third of the survey area mapped as mostly high capability for perennial horticulture, while only a small area falls into this category for annual horticulture.

As shown in Table 5.1, we mapped only 584ha of soil-landscape units that are mostly high capability land for annual horticulture (capability code A2). This does not mean that all the high capability land is only in these map units. There are also significant areas of high capability land in the B1 and B2 map units (Dominantly fair and Mostly fair capability, respectively), but these units also contain large areas of lower capability land.

For example, Dandaragan 1 plateau phase (222Da_1d) covers 4154ha. We estimate about 30% (about 1250ha) of this map unit is Class 1 and Class 2 for annual horticulture, but this is less than half of the map unit. About 45% (2050ha) of the map unit is rated as Class 3, and therefore it has been assigned capability code B1 (Table 5.3).

The main reason for much of the Dandaragan System rating lower for annual horticulture than perennial horticulture is the sloping nature of the terrain. While the ands are good quality, many of them occur on slopes with gradients of 5–10%. These areas rate as Class 3 for annual horticulture because of the risk of water erosion. While it is possible to produce good crops, greater effort and expense is required to mitigate the risk of water erosion and this may involve taking some land out of production.

Table 5.3 Land capability codes for soil-landscape subsystems and phases in the Dinner Hill focus area

Soil-landscape subsystem or phase	Symbol	Area (ha)	Capability code	
			Annual horticulture	Perennial horticulture
Agaton 1 plain phase	222Ag_1c	34	C2	C2
Agaton 5 low dunes phase	222Ag_5a	454	C2	C2
Agaton 5 damp swales phase	222Ag_5d	156	C2	C2
Coalara 1 subsystem	222Co_1	363	C2	C2
Coalara 3 crests phase	222Co_3a	470	C1	C1
Coalara 3 breakaway phase	222Co_3c	57	B1	A2
Coalara 5 plain phase	222Co_5a	3877	C1	C1
Coalara 6 valley slope phase	222Co_6a	3446	B2	B2
Coalara 6 colluvial phase	222Co_6b	47	B1	B1
Coalara 6 minor valley phase	222Co_6c	111	C2	C2
Capitella 1 sandy gravel phase	222Cp_1a	109	B2	B2
Capitella 2 yellow phase	222Cp_2a	640	B2	B2
Capitella 4 York gum phase	222Cp_4b	17	A2	A1
Capitella 5 plain phase	222Cp_5c	2175	C1	C1
Capitella 6 low dunes phase	222Cp_6a	675	C1	C2
Capitella 6 wet phase	222Cp_6c	49	C2	C2
Capitella 7 diatomite phase	222Cp_7d	267	C2	C2
Dandaragan 1 crest phase	222Da_1a	894	B1	A2
Dandaragan 1 small crest phase	222Da_1b	52	B1	A1
Dandaragan 1 stripped slope phase	222Da_1c	88	B2	A2
Dandaragan 1 plateau phase	222Da_1d	4154	B1	A2
Dandaragan 1 pale phase	222Da_1e	117	C1	C1

(continued)

Table 5.3 continued

Soil-landscape subsystem or phase	Symbol	Area (ha)	Capability code	
			Annual horticulture	Perennial horticulture
Dandaragan 2 yellow phase	222Da_2a	7363	B2	B2
Dandaragan 2 pale phase	222Da_2b	655	C1	C1
Dandaragan 3 subsystem	222Da_3	9970	B1	A1
Dandaragan 4 slopes phase	222Da_4a	818	B1	A1
Dandaragan 4 breakaway phase	222Da_4b	34	B1	A1
Dandaragan 5 subsystem	222Da_5	64	B1	B1
Dandaragan 6 subsystem	222Da_6	567	A2	A1
Dandaragan 7 dry phase	222Da_7a	747	B1	B2
Dandaragan 7 wet phase	222Da_7b	368	C2	C2
Dandaragan 8 typical phase	222Da_8a	515	C2	C2
Dandaragan 9 subsystem	222Da_9	22	C2	C2
Rowes 1 typical phase	222Rw_1a	865	B1	A2
Rowes 1 pale phase	222Rw_1b	1007	B2	B2
Rowes 2 subsystem	222Rw_2	2051	B1	B1
Rowes 3 typical phase	222Rw_3a	6909	B1	B1
Boothendarra 3 subsystem	224Bh_3	22	B1	A1
Boothendarra 4 subsystem	224Bh_4	1	B1	A1
Boothendarra 5 subsystem	224Bh_5	1	B1	A1

Note: Appendix B provides detailed descriptions of the soil-landscape subsystems and phases.

5.1 Very high (Class 1) to high (Class 2) capability land

Map units with mainly a high to very high capability for perennial horticulture tend to be in the dissected greensand terrain of the Dandaragan System in the west and south of the focus area. This system has a high proportion of good quality coloured sands. These sands have ample rooting depth, they are free draining, and they have moderate moisture- and nutrient-holding capacities.

Larger map units that are mostly classes 1 and 2 for perennial horticulture are generally in Dandaragan subsystems and phases, mainly 222Da_3, 222Da_1d, 222Da_4a and 222Da_1a.

Rowes 3 typical phase (222Rw_3a) and Dandaragan 2 yellow phase (222Da_2a) also have large areas of classes 1 and 2 land, but with more class 3, 4 and 5 land.

As discussed above, many of these good coloured sands found in the Dandaragan System (e.g. map units 222Da_3 and 222Da_4a) are on sloping land with a higher water erosion risk and are rated as Class 3 for annual horticulture.

Wind erosion is always a consideration on sandy surfaced soils, even these good coloured sands. The loose sandy nature of the topsoils and the relatively open, exposed landscape mean that most of the focus area has a moderate wind erosion hazard. For perennial crops, the greatest risk is sandblasting during seedling establishment. Once the trees, shrubs or vines mature, they will provide some protection for the soil. Establishing groundcover between rows will reduce the risk, but this can result in competition for nutrients and water resources.

Wind erosion risk is a recurring problem for annual crops. While shelterbelts and windbreaks may reduce the risk, it will probably be necessary to irrigate the soils between ground preparation and when the crops are established, thereby increasing the total water requirement.

Soil acidity, requiring liming, may develop on some of these sands, and non-wetting issues can arise.

5.2 Fair (Class 3) capability land

Map units with mainly fair capability for perennial horticulture are generally in the central and eastern portion of the Dinner Hill focus area. This includes most of the Rowes System and parts of the Dandaragan and Coalara systems.

Limited water-holding capacity of the ‘fair quality sands’ is the main factor for rating land as Class 3 for annual and perennial horticulture. Map units with a large area of these sands include Rowes 3 typical phase (222Rw_3a), Dandaragan 2 yellow phase (222Da_2a), Coalara 6 valley slope phase (222Co_6a) and Rowes 2 subsystem (222Rw_2).

Careful management of irrigation and fertiliser application is required on these sands. Frequent irrigation helps to ensure that crops do not suffer moisture stress, especially during the hot and windy summer months. There is a fine line between providing the crops with sufficient water and over-watering, which is not only wasteful but can leach fertilisers below the root zone and contribute to nutrient export.

As discussed above, water erosion is a Class 3 limitation for annual horticulture on slopes with gradients of 5–10% in the Dandaragan System. Cultivating these slopes increases the erosion risk. Furrows should run on a slight grade off the contour to avoid channelling water flows directly down slope or create an impediment to water movement off the slope. Earthworks to manage surface flows may be required on these slopes.

Wind erosion risk results in a Class 3 rating for more exposed sands on exposed ridge crests. Rooting depth is also a Class 3 limitation for perennial horticulture in some locations, especially on ridge crests.

5.3 Low (Class 4) to very low (Class 5) capability land

Map units with mainly a low to very low capability for annual and perennial horticulture are more common in the east of the focus area. They include map units dominated by ‘poor quality’ sands in the Capitella and Coalara systems. Ridge crests with shallow soils fall into this category, as do low-lying areas and valley floors subject to waterlogging, salinity and flooding.

6 LMUs in the Dinner Hill focus area

6.1 The land management unit (LMU) concept

In a report on the Kent River Catchment, Kelly (1995) describes LMUs as a reasonably homogeneous area of land that responds in a similar way under similar management.

The concept of LMUs is to provide a pragmatic paddock-scale mapping tool for farm planning. We use it here as a communication tool to outline the main characteristics, opportunities and constraints of land in the Dinner Hill area in a generalised way.

We simplified the proportional soil mapping data into 16 LMUs for the focus area to reflect the specific physical characteristics and the requirements and management practices for the potential land uses (Table 6.1).

Table 6.1 Land management units (LMUs) in the Dinner Hill focus area

LMU name	Main WA Soil Group in LMU (and main soil group qualifiers)	Area (ha)	Percentage of focus area (%)
Fair coloured sands	Yellow deep sand with Red and Brown deep sands (mostly 'fair sand, very deep' qualifier)	10 800	21
Good coloured sands	Red deep sand with Yellow and Brown deep sands (mostly 'good sand, very deep' qualifier) and some Yellow and Red sandy earths	10 750	21
Poor coloured sands	Yellow deep sand (mostly 'poor sand, very deep' qualifier)	7 650	15
Poor pale sands	Pale deep sand and Gravelly pale deep sand (mostly 'poor sand, very deep' qualifier)	5 900	12
Good gravels	Duplex sandy gravel ('good sand, very deep' qualifier) and Deep sandy gravel ('neutral subsoil' qualifier)	4 850	10
Shallow soils	Shallow gravel and Pale shallow sand (various qualifiers)	2 250	4
Fair pale sands	Pale deep sand (mostly 'poor sand, very deep' qualifier) with some Pale sandy earths	1 900	4
Unsuitable landform[a]	Various soils	1 850	3
Very shallow or rocky[a]	Shallow gravel, Red shallow loam and Pale shallow sand (mostly 'very shallow rock substrate' qualifier)	1 300	3
Good loams	Red and Brown loamy earths (mostly 'good neutral subsoil' qualifier)	1 150	2
Poor gravels	Deep sandy gravel (mostly 'poor sand, very deep' qualifier)	850	2
Good sandy duplexes	Yellow/brown and Red deep sandy duplexes ('good neutral subsoil' qualifier)	700	1
Good heavy soils	Shallow sandy and loamy duplex soils (mostly 'good neutral subsoil' qualifier)	150	<1
Saltland[a]	Various soils	100	<1
Poor clays, loams and duplexes[a]	Yellow/brown shallow sandy duplex ('poor subsoil' qualifier)	50	<1

a LMU is unsuitable for irrigated agriculture

We have used descriptive terminology, such as good, fair and poor, for some of the LMUs. These terms are based on soil qualifiers developed for WA Soil Groups (Schoknecht & Pathan 2013). The qualifiers provide extra information about a soil to distinguish properties relative to land management, such as soil texture, soil depth or soil chemistry. More details about soil qualifiers and their definitions are in Schoknecht and Pathan (2013). Table A1.4 in Appendix A shows how qualifiers are used in map unit descriptions.

In the Dinner Hill focus area, Good and Fair coloured sands are the most common LMUs, together over 40% of the area. The Poor coloured and pale sands LMUs cover a further 25% with the Good gravels making up another 10%. The remaining 25% of the focus area contains a mix of minor LMUs.

6.2 Distribution of LMUs

Sandy or gravelly LMUs dominate most of the focus area. Through soil development and geomorphology, some LMUs tend to occur together. These combinations relate to the soil-landscape systems. The Coalara (222Co) and Capitella (222Cp) systems tend to have Pale and Poor coloured sands, whereas Dandaragan (222Da) and Rowes (222Rw) systems tend to have Good coloured sands. Gravels tend to be associated with Poor pale sands, and if they occur on breakaway slopes, they are associated with heavy soils (Figure 6.1).

The most distinct co-occurrence is the Saltland LMU and the Unsuitable landform LMU, both mostly being in drainage lines. The loamy and shallow soils tend to occur together on hillslopes below breakaways or where the Gingin Chalk is outcropping.

The distribution of LMUs in the map units are in Appendix F. The expected distribution of each LMU across the focus area is presented within the LMU information sheets in Section 7.

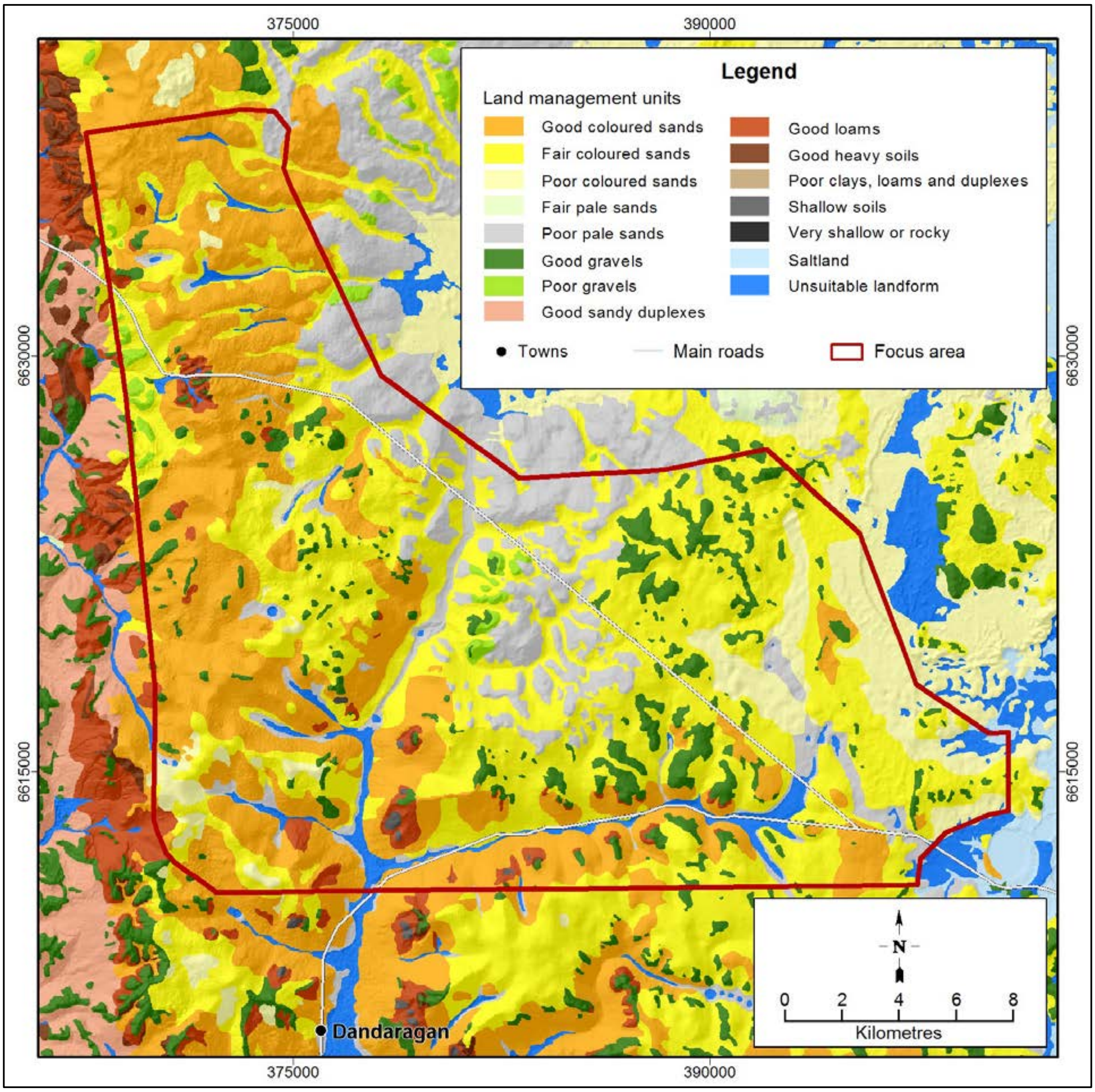


Figure 6.1 Dominant land management units (LMUs) in the Dinner Hill focus area

6.2.1 How to use LMUs

LMUs have characteristics that allow their management as a single unit for specific enterprises. This considers the nature of the soils and landforms, as well as how they interact with each other and the intended land use.

To assist landholders or potential investors interpret this information we have provided the following:

- the LMU key in Section 6.5 to identify LMUs in the field
- The LMU information sheets (Section 7) complementing the LMU key and indicate the most significant management issues and opportunities.
- The most likely WA Soil Groups (Schoknecht & Pathan 2013) occurring within each LMU, and descriptions of representative soil profiles and available soil chemistry are in Appendix E.

6.3 Capability of LMUs

The sands dominant in the focus area possess many good qualities for irrigated agriculture. We found that, with management of wind erosion risk, almost all LMUs in the Dinner Hill focus area have some capability for annual and perennial horticulture. Exceptions to this are a few LMUs with significant landform and soil limitations: Very shallow or rocky, Unsuitable landform and Saltland LMUs.

The poorer sands — Poor pale sands and Poor coloured sands LMUs — are less suitable for horticulture, largely because of limited water- and nutrient-holding capacity and, as a consequence, management costs are higher because more water and nutrients are required.

The common Good gravels LMU may not be as well suited to root crops. This LMU can be highly suitable to some perennial crops where its higher subsurface moisture retention can be beneficial.

While the LMUs with heavier soils — Good sandy duplexes, Good loams and Good heavy soils — appear highly suitable for horticulture, they cover only a very small portion of the focus area and occur in small patches.

6.4 Suitable crops

The LMU information sheets in Section 7 include an indication of potential crops for consideration. These are only suggestions as detailed site assessments must be made prior to any development. Table 6.2 provides a general overview of which LMUs are worth considering for particular crops. Van Wyk (2019) compiled detailed information about suitable crops for the Midlands area.

These suggestions are based on capability and include degradation risks, but other business considerations may sway decisions to grow crops on LMUs with lower capability and higher levels of management rather than on more productive, easier managed soils. For example, pale sands will generate more management costs and challenges than coloured sands, but in the case of root crops, growing on pale sands means the product might have lower overall costs to present for market.

Table 6.2 Summary of crop suitability with management considerations for main land management units (LMUs)

LMUs suited for irrigation	Potential irrigated crops for the Dinner Hill focus area								
	Annual shallow-rooted vegetables ❄	**Annual fruits** ❄	**Root crops** ❄	**Pastures/ fodder** ❄	**Nut trees** ⛄	**Stone fruit** ⛄	**Citrus trees** ❄	**Other orchard trees** ❄	**Vineyard fruit** ⛄
Poor pale sands 💧 💨 💨	?	?	✓	?	?	?	?	?	?
Poor coloured sands 💧 💨 💨	?	?	✓	?	?	?	?	?	?
Fair coloured sands 💧 💨 💨	✓	✓	✓✓	✓	✓	✓	✓	✓	✓
Fair pale sands 💧 💨 💨	✓	✓	✓✓	✓	✓	✓	✓	✓	✓
Good coloured sands 💨 💨	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Shallow soils 💨 💨	✓	✓	×	✓✓	×	×	×	×	×
Good gravels 💨 💨	✓✓	✓✓	×	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Good heavy soils 💨 💦	✓	✓	×	✓✓	✓	✓	✓	✓	✓
Good sandy duplexes 💨 💨 💦	✓✓	✓✓	✓	✓✓	✓	✓	✓	✓	✓
Good loams 💨 💦	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓

✓✓ = crop is highly suited; ✓ = crop is suited; ? = crop is marginally suited; × = crop is not suited

❄ = crop may be frost sensitive; careful selection of suitable varieties needed for inland frost prone locations

⛄ = chilling of crop is required; crop more suited to inland locations

💧 = high water and nutrient requirement, and nutrient export risk

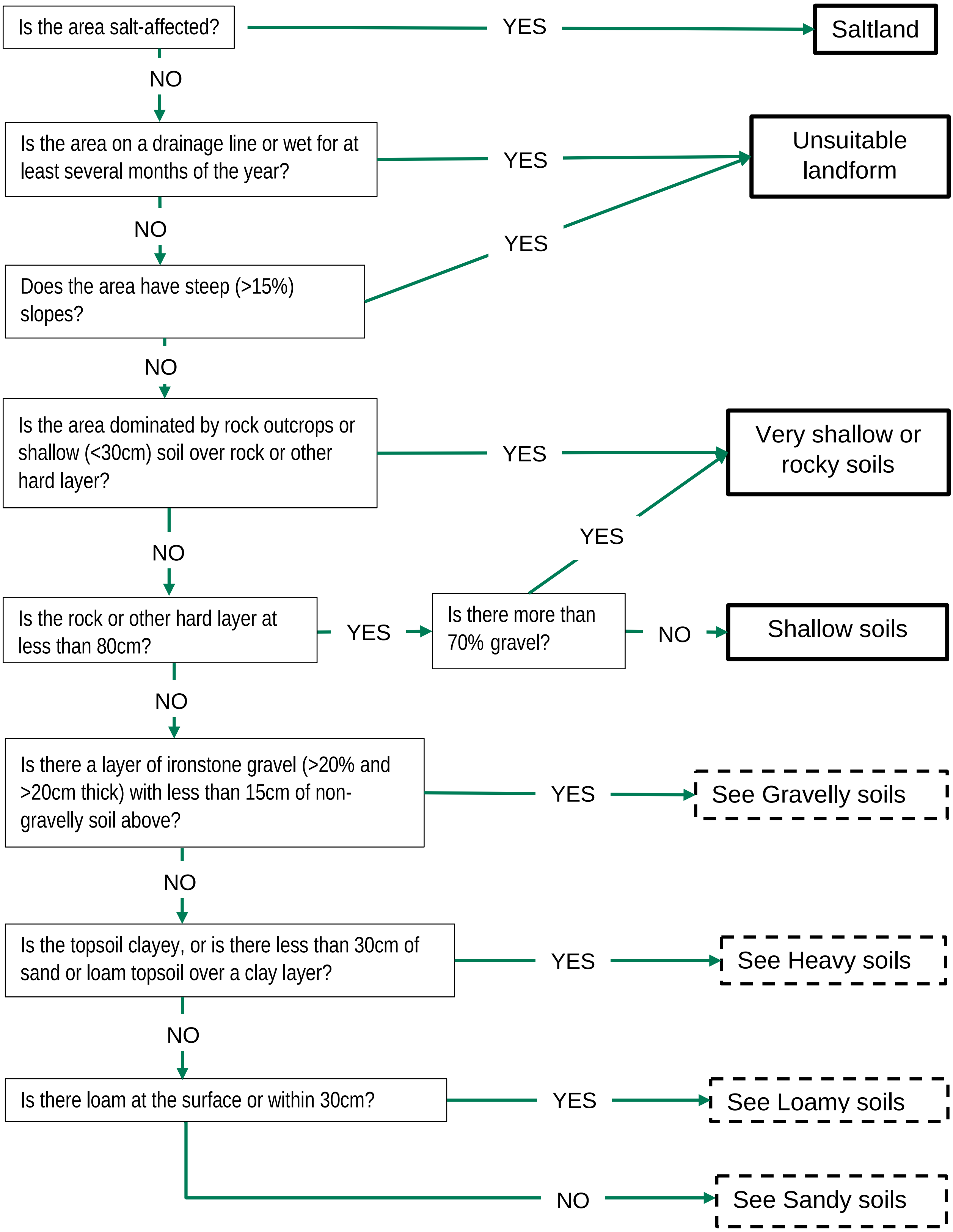
💨 💨 = high wind erosion risk; extensive protection for soils and crops is necessary to avoid degradation

💨 = moderate wind erosion risk; general protection for soils and crops

💦 = optimum quality water is needed to prevent irrigation salinity and soil degradation

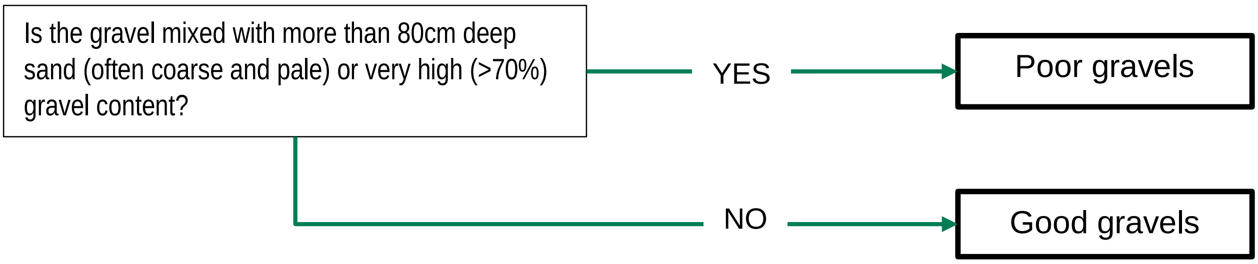
6.5 LMU key

An LMU is a reasonably homogeneous area of land that responds in a similar way under similar management. This key is designed for use at the paddock scale.



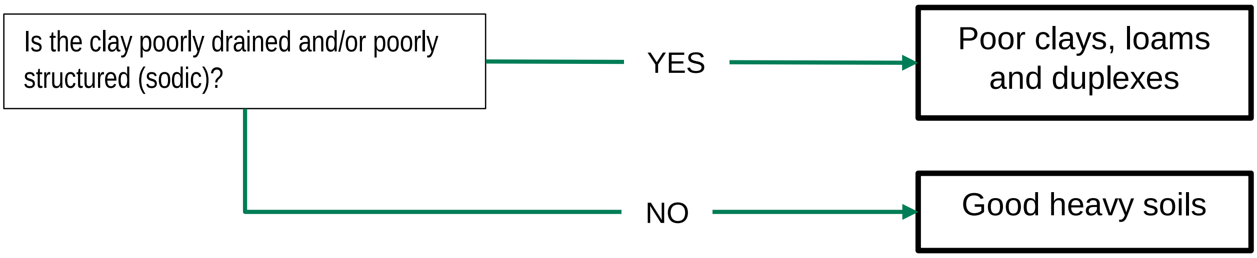
Key to the Gravelly soils

Gravelly soils have a layer at least 20cm thick of more than 20% ironstone gravel with less than 15cm of the non-gravelly soil on top.



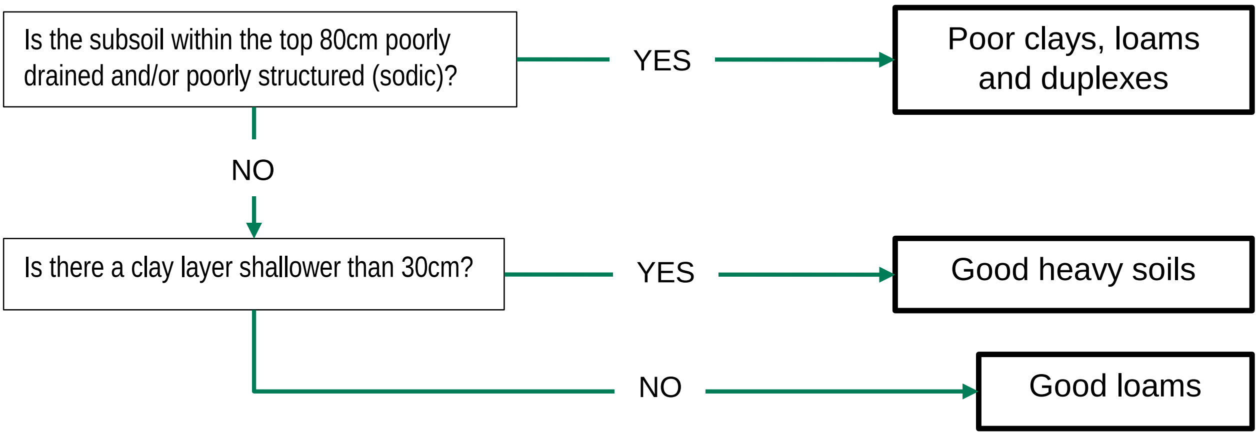
Key to the Heavy soils

The surface of heavy soils is clayey or there is less than 30cm of sand or loam over clay. There is no gravelly layer and no hard layer within 80cm.



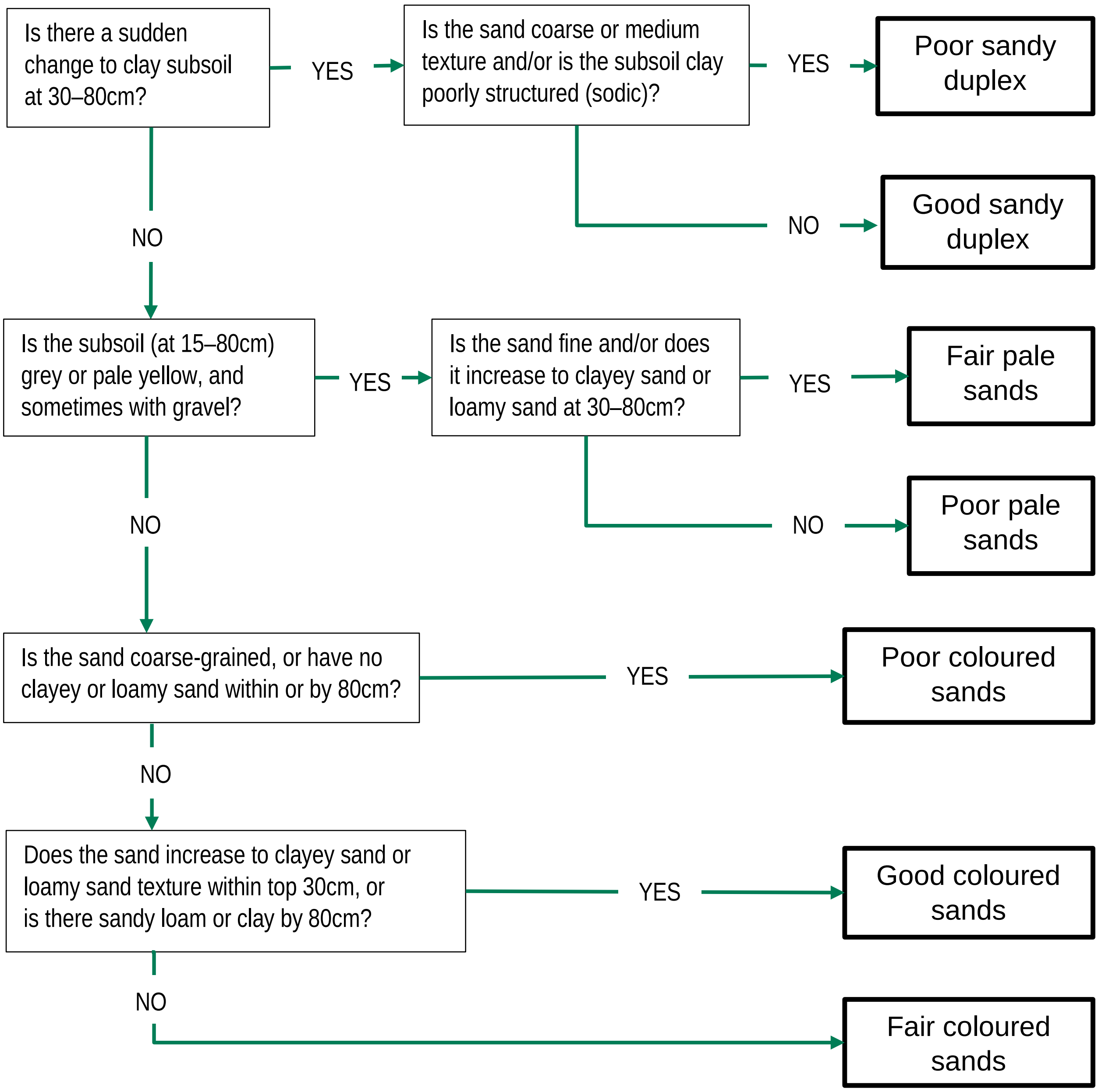
Key to the Loamy soils

There is no clay within the top 30cm of loamy soils. The surface is loamy, or there is loam within the top 30cm. There is no gravelly layer and no hard layer within 80cm.



Key to the Sandy soils

Sandy soils have no clay or loam within the top 30cm. There is no hard layer within 80cm.



7 LMU information sheets for the Dinner Hill focus area

Fair coloured sands LMU

Yellow, red or brown coloured sands with an increase in clay below 30cm. Typical soil profile descriptions of Fair coloured sands are presented in Appendix E.

Identification

The soils associated with this LMU are mainly moderate quality, pale Yellow deep sands. These sands have a fine sandy texture and are paler close to the surface, with not much clay in the top 30cm. The soil texture increases to clayey and loamy sand below 30cm.

Yellow deep sand dominates this LMU, with some brown and red sands also found.

Other names

Pale yellow sand, deep yellow sand

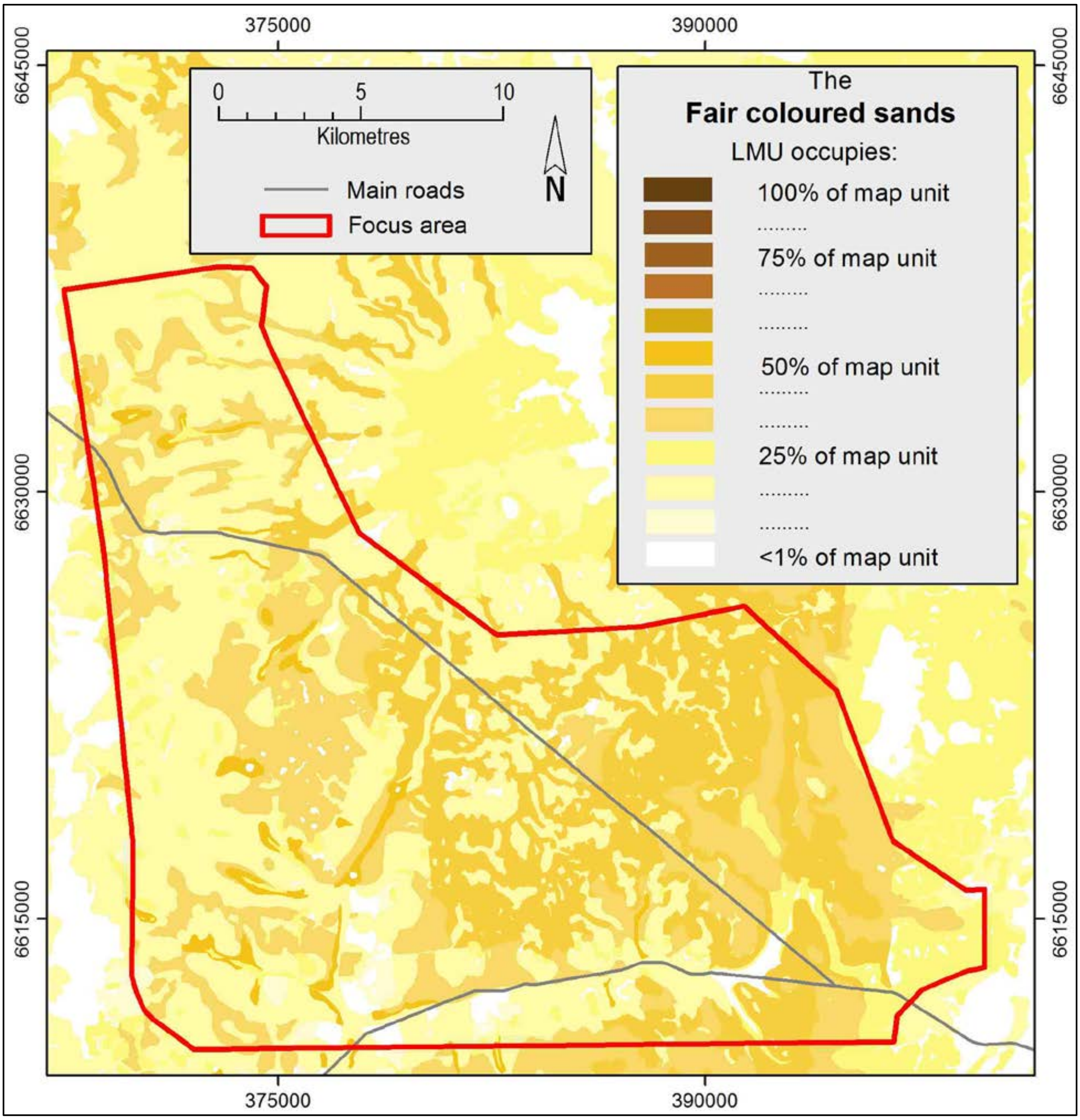
Typical soil profile of Fair coloured sands LMU

Management considerations

- These soils are well suited to root crops because of their loose, sandy nature.
- Judicious fertiliser application is essential to maintain fertility.
- Limited water storage and deep drainage of soils require frequent application of relatively small amounts of water. Subsoils have more clay, with better water-holding capacity than topsoils.
- The risk of wind erosion will necessitate the installation of windbreaks or higher water use to keep topsoils damp.
- The risk of irrigation salinity is low, but salt accumulation may occur in areas of higher evaporation or if water quality is not optimum. Irrigation water will be needed to flush or wash salts from topsoils. Watering will need to be scheduled according to evaporation, crop type and development stage, rather than at set intervals.

Distribution

This LMU covers about 21% of the Dinner Hill focus area. It is relatively common across all the sandplain slopes.



Areas of Fair coloured sands LMU in the Dinner Hill focus area

Potential horticultural crops for Fair coloured sands LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓
Annual fruits	Strawberries	✓
Root crops	Potatoes, carrots	✓✓
Pastures/fodder	Lucerne	✓
Nut trees	Almonds	✓
Stone fruit	Peaches	✓
Citrus trees	Mandarins	✓
Other orchard trees	Olives	✓
Vineyard fruit	Table grapes	✓

✓✓ = crop is highly suited; ✓ = crop is suited; ✗ = crop is not suited

Characteristics

Water storage	**Low**: these sands tend to be low in organic matter and clay content; clay content increases with depth and water storage may improve in relation to clay
Nutrient availability	**Low to very low**: low inherent fertility and added nutrients are readily leached below rooting depth
Rooting conditions	**Good**: loose sandy topsoil and subsoil provides few barriers to root development
Permeability	**Rapidly drained**: soils are highly permeable which may lead to nutrient leaching
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Very good**: workability is very good over a wide moisture range

Land management risks

Nutrient export	**High risk**: very limited capacity to retain nutrients so leaching losses are high
Irrigation salinity	**Low risk**: free-draining permeable soils have a lower risk of irrigation salinity
Soil acidity	**High risk**: where surface and subsurface pH is <5.5, periodic monitoring is advisable and liming is recommended
Soil structure decline	**Low–moderate risk**: traffic pan can develop from passes of heavy machinery
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Low–moderate risk**: generally rapidly drained, but erosion problems can occur on slopes greater than 3% and on soil which are water-repellent soils
Wind erosion	**Very high to extreme risk**: soils are sandy and have a loose to soft surface; surface protection is required and windbreaks are necessary

Good coloured sands LMU

Red, yellow or brown coloured deep sands and sandy earths with loamy or clayey sand textures found in the top 30cm. Typical soil profile descriptions of Good coloured sands are in Appendix E.

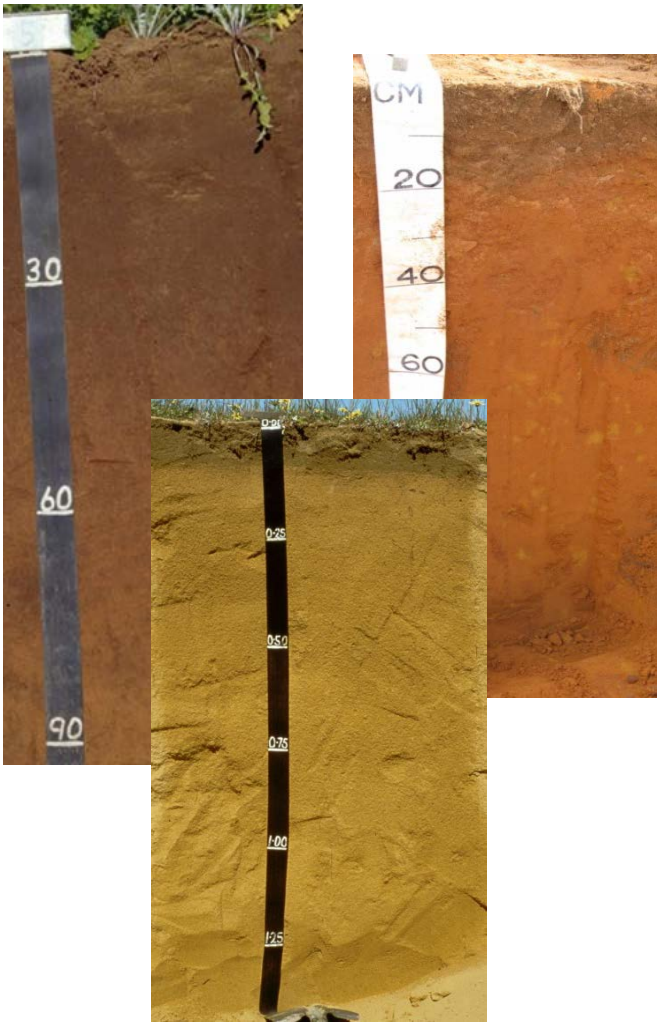
Identification

The deep, sandy soils associated with this LMU are usually strong-coloured red or yellow, with clayey sand or loamy sand texture dominating the top 30cm and extending to below 80cm. Often, the clay content of the subsoil gradually increases to a sandy loam or light clay texture (sandy earth soils).

In the Dinner Hill area Red deep sand dominates this LMU, with Yellow and Brown deep sands also common.

Other names

Good yellow sand, Good sandplain, Red sandy loam, Yellow sandplain



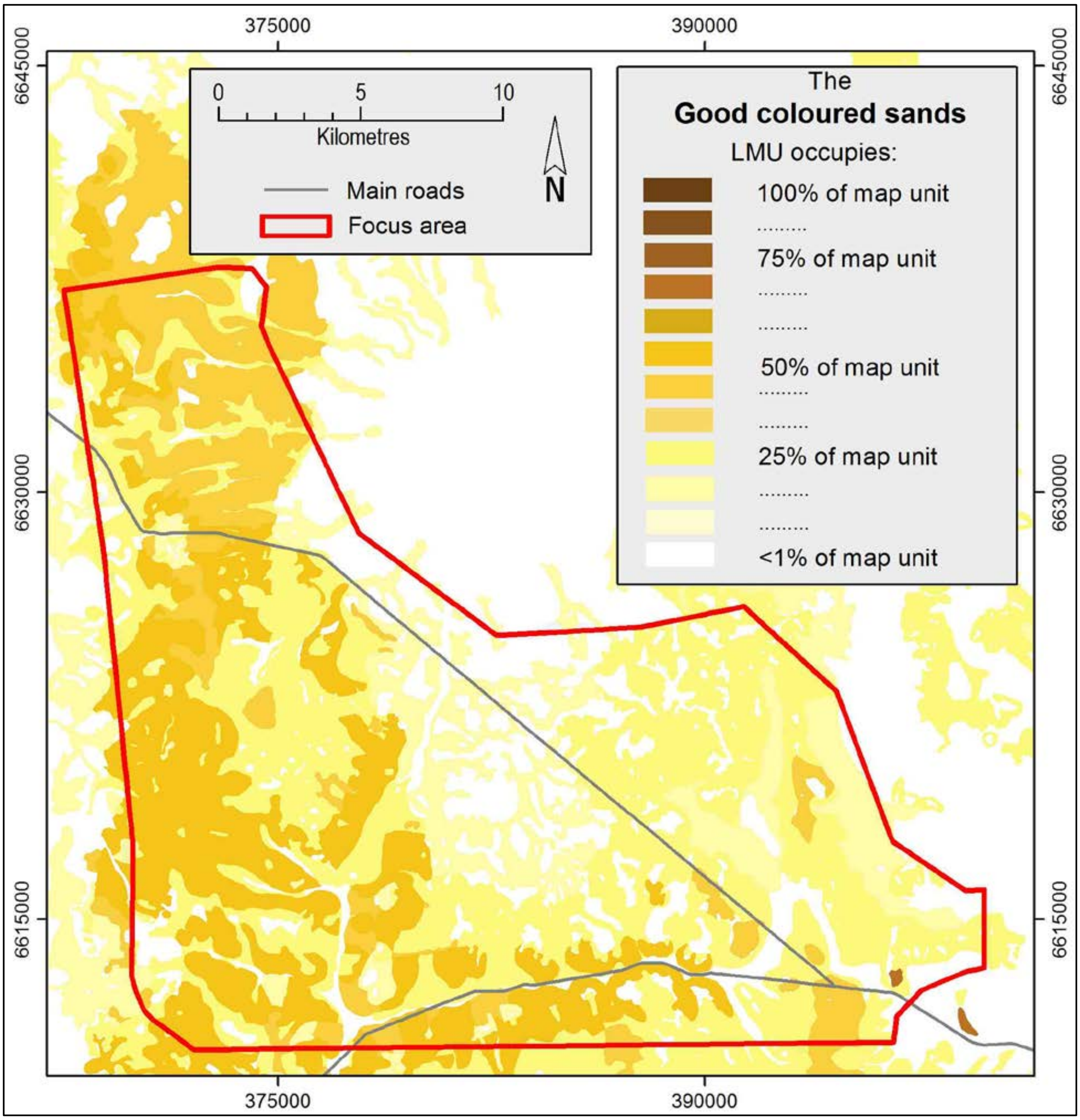
Typical soil profiles of Good coloured sands LMU

Management considerations

- These soils are well suited to root crops because of their loose, sandy nature.
- Compaction pans need managing because they may hinder root development.
- The risk of wind erosion will necessitate the installation of windbreaks or higher water use to keep topsoils damp.
- The risk of irrigation salinity is low, but salt accumulation may occur in areas of higher evaporation or if water quality is not optimum. Irrigation water will be needed to flush or wash salts from topsoils. Watering will need to be scheduled according to evaporation, crop type and development stage, rather than at set intervals.

Distribution

This LMU makes up about 21% of the total focus area. These soils are found mainly on sandplain slopes above valley floors and upland plains, and are more frequent around Dandaragan, extending in a band to the north and south.



Areas of Good coloured sands LMU in the Dinner Hill focus area

Potential horticultural crops for Good coloured sands LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓✓
Annual fruits	Strawberries	✓✓
Root crops	Potatoes, carrots	✓✓
Pastures/fodder	Lucerne	✓✓
Nut trees	Almonds	✓✓
Stone fruit	Peaches	✓✓
Citrus trees	Mandarins	✓✓
Other orchard trees	Olives	✓✓
Vineyard fruit	Table grapes	✓✓

✓✓ = crop is highly suited; ✓ = crop is suited; × = crop is not suited

Characteristics

Water storage	**Moderate**: these sands either have fine grains or some clay content, resulting in higher available water content than poorer sands
Nutrient availability	**Moderate**: low inherent fertility and added nutrients are readily leached below rooting depth; the iron and clay in these coloured sands will hold some phosphorous
Rooting conditions	**Very deep**: loose, sandy topsoil and subsoil provides few barriers to root development; few gravels present
Permeability	**Rapidly drained**: the soils are highly permeable and typically occur in elevated, well-drained positions
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Very good**: workability is very good over a wide moisture range

Land management risks

Nutrient export	**Fair risk**: retention of applied fertiliser is fair to good
Irrigation salinity	**Low risk**
Soil acidity	**High risk**: where surface and subsurface pH is <5.5, periodic monitoring is advisable and regular liming is recommended
Soil structure decline	**High risk**: possibility of traffic pan developing
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Moderate risk**: erosion can be a problem on these soils where slopes >3%
Wind erosion	**Very high to extreme risk**: soils are sandy and have a loose to soft surface; surface protection is required in summer and autumn and windbreaks are necessary

Poor coloured sands LMU

Soils with over 80cm of medium-grained yellow or brown coloured sands with minimal clay content. Typical soil profile descriptions of Poor coloured sands are in Appendix E.

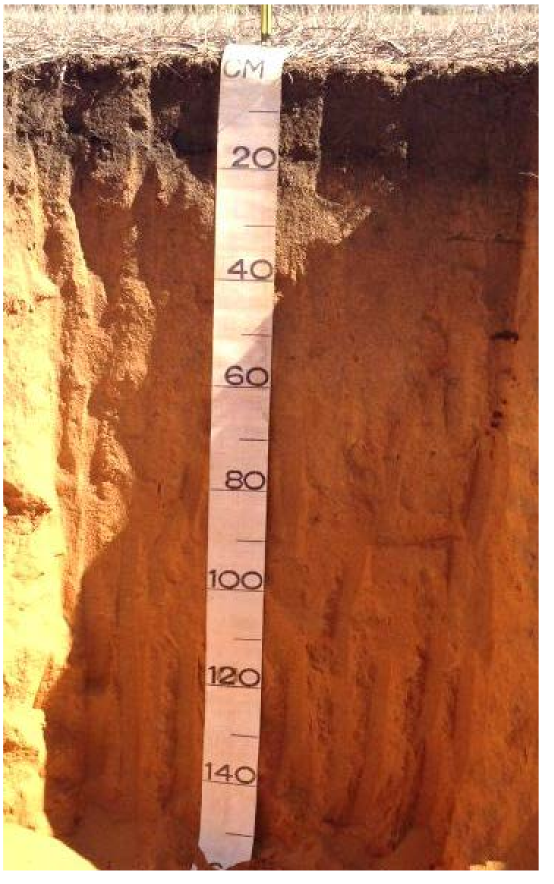
Identification

The soils associated with this LMU are poor quality, coloured, medium- to fine-grained sands with little clay content found in the top 80cm.

Poor Yellow deep sands dominate this LMU, with minor areas of Brown deep sands.

Other names

Deep yellow sand



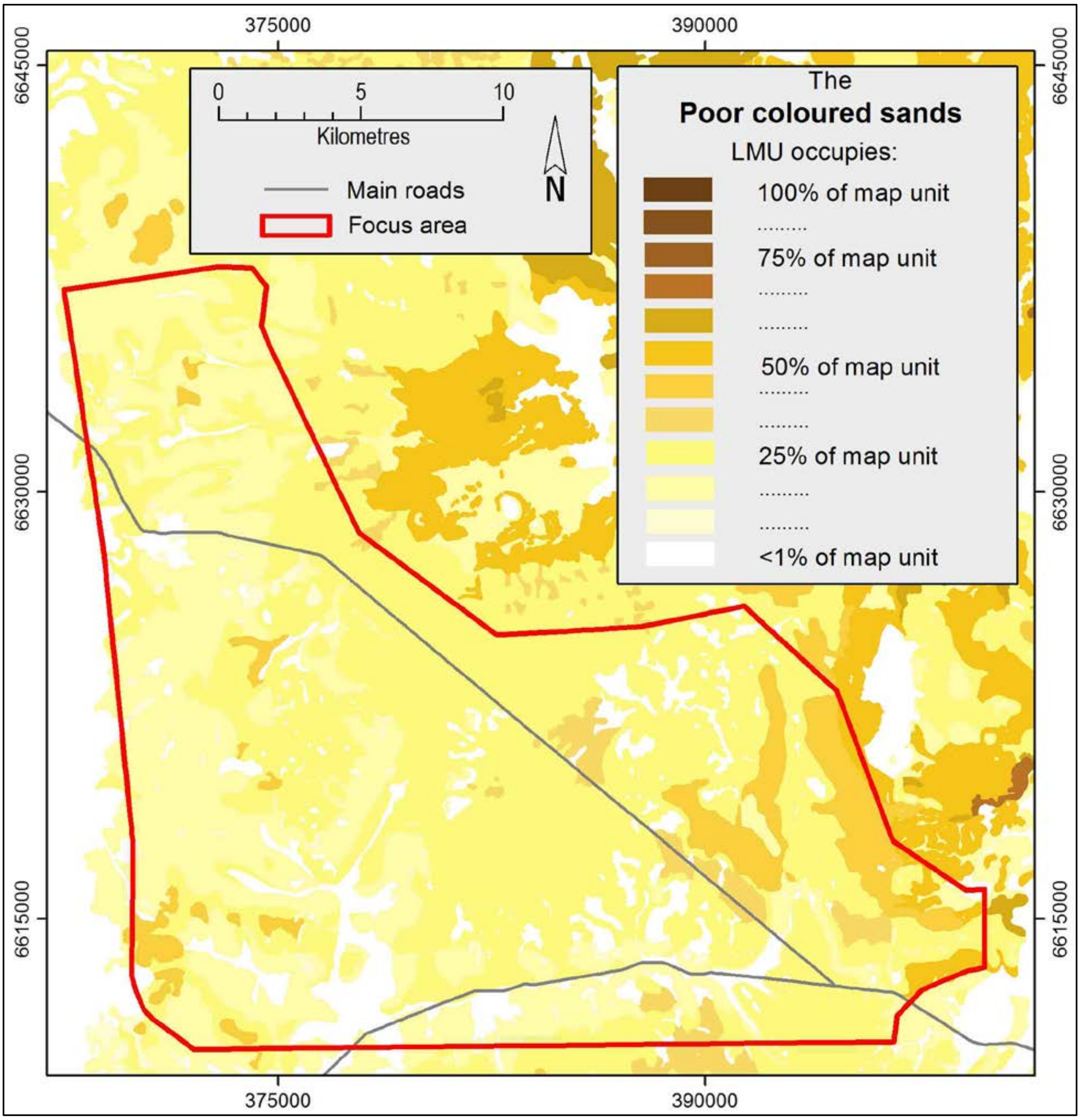
Typical soil profile of Poor coloured sands LMU

Management considerations

- Some of these soils may be considered adequate for irrigated crops; however, large investment and careful management would be required to overcome production hazards.
- These soils are generally suited to root crops because of their loose, sandy nature. Coarse sands may not be well suited for some sensitive root crops (e.g. carrots).
- Judicious fertiliser application is essential to maintain fertility.
- Limited water storage and rapid drainage of soils require frequent application of relatively small amounts of water.
- The risk of wind erosion will necessitate the installation of windbreaks or higher water use to keep topsoils damp.
- Periodic monitoring of surface and subsurface pH is recommended.
- The low phosphorus retention index (PRI) of these soils makes them a source of nutrient leaching.

Distribution

Poor coloured sands LMU makes up about 15% of the Dinner Hill focus area. It is located mainly on gentler hillslopes and plains.



Areas of Poor coloured sands LMU in the Dinner Hill focus area

Potential horticultural crops for Poor coloured sands LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	?
Annual fruits	Strawberries	?
Root crops	Potatoes, carrots	✓
Pastures/fodder	Lucerne	?
Nut trees	Almonds	?
Stone fruit	Peaches	?
Citrus trees	Mandarins	?
Other orchard trees	Olives	?
Vineyard fruit	Table grapes	?

✓✓ = crop is highly suited; ✓ = crop is suited; ? = crop is marginally suited;
× = crop is not suited

Characteristics

Water storage	**Low**: these sands have poor water-holding capacity because of their low organic matter and clay content
Nutrient availability	**Low to very low**: low inherent fertility and added nutrients are readily leached below the rooting depth
Rooting conditions	**Good**: loose, sandy topsoil and subsoil provides few barriers to root development
Permeability	**Rapidly drained**: these soils are highly permeable and may lead to excess leaching of nutrients
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Very good**: workability is good over a wide moisture range

Land management risks

Nutrient export	**High risk**: very limited capacity to retain nutrients; leaching losses are high
Irrigation salinity	**Low risk**
Soil acidity	**High risk**: prone to acidification; regular surface and subsurface monitoring is advisable
Soil structure decline	**Low risk**: loose, single-grained structureless soil
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Low–moderate risk**: erosion can be a problem below gravel outcrops and where slopes are >3%
Wind erosion	**Very high to extreme risk**: soils are sandy and have a loose to soft surface; surface protection is required and windbreaks are necessary

Poor pale sands LMU

Pale soils with over 80cm of coarse or gritty-grained sands and gravels. Typical soil profile descriptions of Poor pale sands are presented in Appendix E.

Identification

This LMU is made up of a group of soils that have qualities considered poor for irrigated agriculture. They include poor, pale (gutless) deep sands and coarse, pale sand over gravel

This LMU features a co-dominance of poor Pale sands and sands over gr

Other names

Gutless grey sand, Grey sandplain, Sand over gra yellow sand

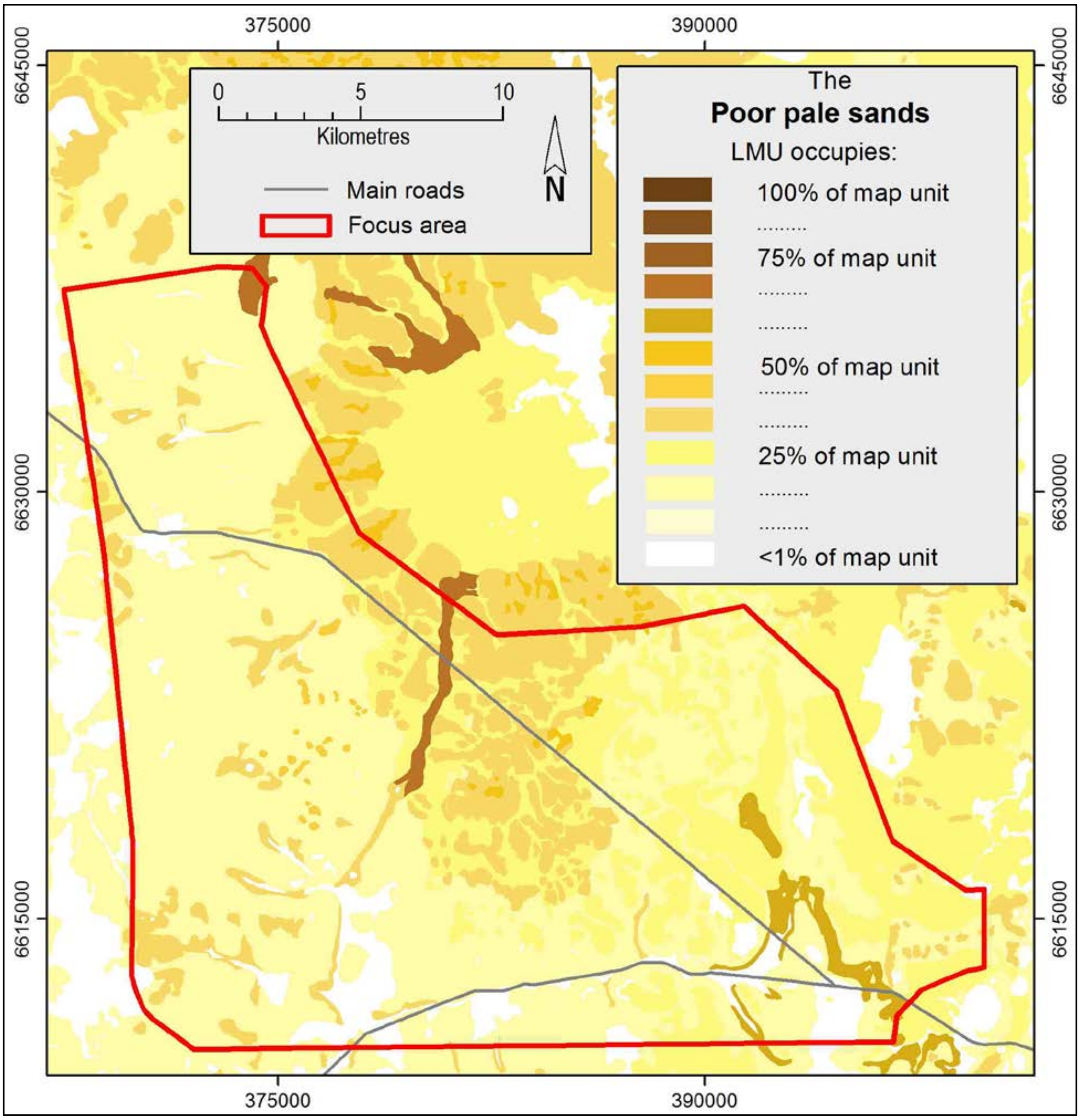
Typical soil profiles of Poor pale sands LMU

Management considerations

- Some of these soils may be considered adequate for irrigated crops; however, large investment and careful management would be required to overcome production hazards.
- These soils are generally suited to root crops because of their loose, sandy nature. Coarse sands may not be well suited for some sensitive root crops (e.g. carrots).
- Judicious fertiliser application is essential to maintain fertility.
- Low water storage and rapid deep drainage of soils require frequent application of relatively small amounts of water.
- The risk of wind erosion will necessitate the installation of windbreaks and higher water use to keep topsoils damp.
- Periodic monitoring of surface and subsurface pH is advisable.
- The low phosphorous retention index (PRI) of these soils makes them a source of nutrient leaching.

Distribution

This LMU covers 12% of the Dinner Hill focus area, generally on slopes, hillcrests and upland plains.



Areas of Poor pale sands LMU in the Dinner Hill focus area

Potential horticultural crops for Poor pale sands LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	?
Annual fruits	Strawberries	?
Root crops	Potatoes, carrots	✓
Pastures/fodder	Lucerne	?
Nut trees	Almonds	?
Stone fruit	Peaches	?
Citrus trees	Mandarins	?
Other orchard trees	Olives	?

✓✓ = crop is highly suited; ✓ = crop is suited; ? = crop is marginally suited;
× = crop is not suited

Characteristics

Water storage	**Low**: these sands have poor water-holding capacity because of low organic matter and clay content
Nutrient availability	**Low to very low**: low inherent fertility; added nutrients are readily leached below the rooting depth
Rooting conditions	**Good**: loose, sandy topsoil and subsoil generally provides few barriers to root development
Permeability	**Rapidly drained**: these soils are highly permeable and may result in excess leaching of nutrients
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Very good**: workability is very good over a wide moisture range

Land management risks

Nutrient export	**High risk**: very limited capacity to retain nutrients; leaching losses are high
Irrigation salinity	**Low risk**
Soil acidity	**High risk**: prone to acidification
Soil structure decline	**Low–moderate risk**: traffic pan may occur in subsoil
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Low–moderate risk**: erosion can be a problem below gravel outcrops, upslope, and on slopes >3%
Wind erosion	**Very high to extreme risk**: soils are sandy and have a loose to soft surface; surface protection is required and windbreaks are necessary

Good gravels LMU

Ironstone gravels mixed with yellow-brown loamy or clayey sand, or sandy loam to deeper than 80cm, or over a clay layer below 30cm. Typical soil profile descriptions of Good gravels are presented in Appendix E.

Identification

Gravels are soils with more than 20% ironstone gravel in the top 15cm. Soils belonging to this LMU are generally gravelly sands over clay, Deep sandy gravel and minor areas of Loamy gravel.

Other names

Buckshot gravel, forest gravel, pea gravel

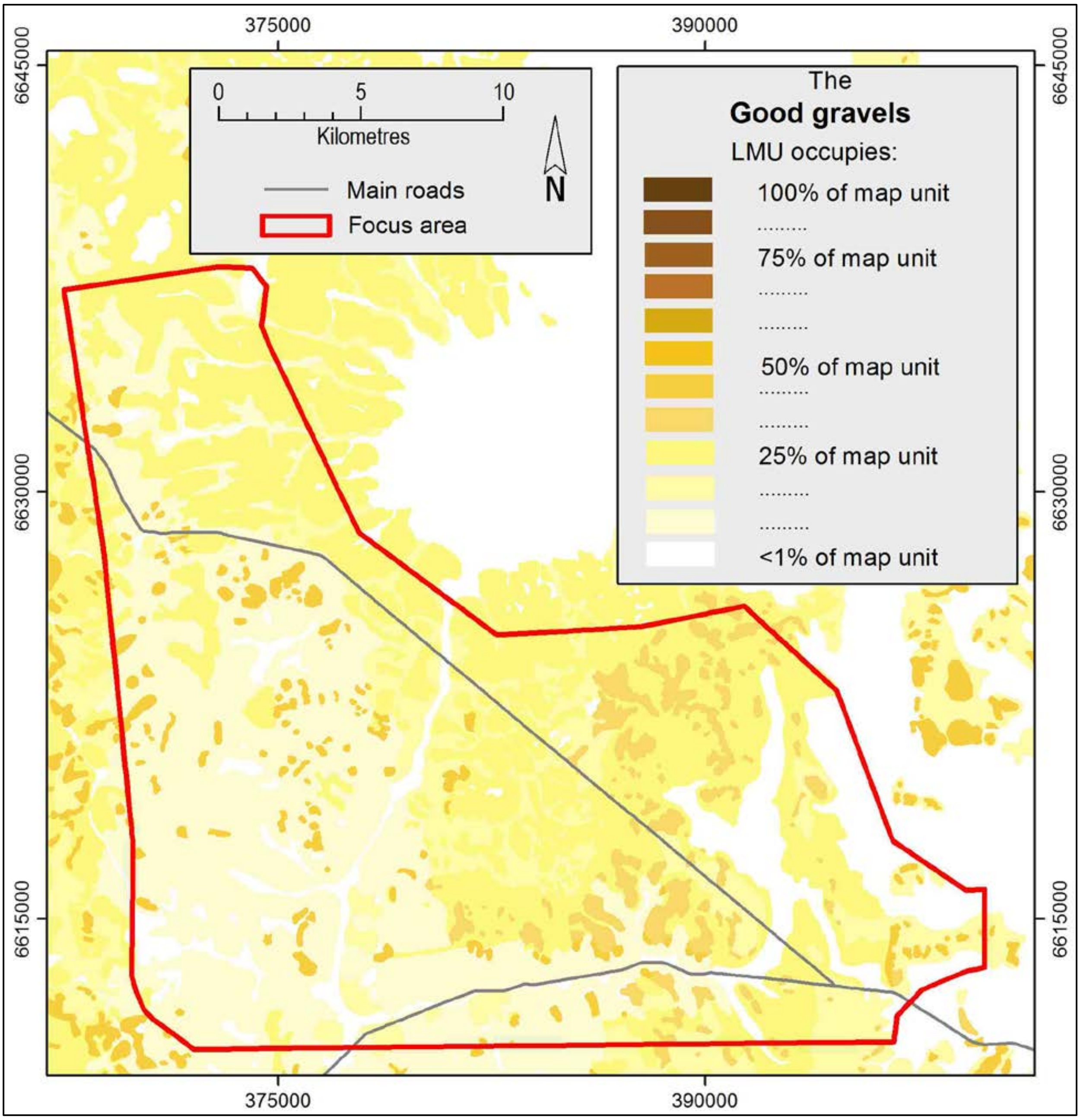
Typical soil profile of Good gravels LMU

Management considerations

- These soils are not well suited to root crops because of their gravelly nature.
- Limited water storage and deep drainage of soils require frequent application of relatively small amounts of water.
- The risk of wind erosion will necessitate the installation of windbreaks or higher water use to keep topsoils damp.
- The risk of irrigation salinity is low, but salt accumulation may occur in areas of higher evaporation or if water quality is not optimum. Irrigation water will be needed to flush or wash salts from topsoils. Watering will need to be scheduled according to evaporation, crop type and development stage, rather than at set intervals.
- Careful monitoring of irrigation is required to prevent a perched watertable forming above the clay layer in duplex gravels.

Distribution

This LMU makes up about 10% of the soils in the Dinner Hill focus area. It generally occurs on hill crests and steeper slopes.



Areas of Good gravels LMU in the Dinner Hill focus area

Potential horticultural crops for Good gravels LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓✓
Annual fruits	Strawberries	✓✓
Root crops	Potatoes, carrots	×
Pastures/fodder	Lucerne	✓✓
Nut trees	Almonds	✓✓
Stone fruit	Peaches	✓✓
Citrus trees	Mandarins	✓✓
Other orchard trees	Olives	✓✓
Vineyard fruit	Table grapes	✓✓

✓✓ = crop is highly suited; ✓ = crop is suited; × = crop is not suited

Characteristics

Water storage	**Moderately low**: gravel content may limit water-holding capacity of the soil; duplex gravels have a lower water-storage capacity
Nutrient availability	**Moderate**
Rooting conditions	**Good**: few barriers to root development, although not well suited to root crops where shape is important
Permeability	**Well to rapid**: very gravelly soils increase permeability
Trafficability	**Good**
Soil workability	**Very good**: workability is very good over a wide moisture range

Land management risks

Nutrient export	**Low–moderate risk**
Irrigation salinity	**Low risk**
Soil acidity	**Moderate risk**: periodic monitoring is advisable
Soil structure decline	**Moderate risk**
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Moderate risk**: erosion can be a problem on these soils where slopes are >3%
Wind erosion	**Very high risk**: soils are sandy and have loose to soft surface; surface protection is required and windbreaks are necessary

Shallow soils LMU

Soils with rock or other hard layer at 30–80cm below the surface. Typical soil profile descriptions of Shallow soils LMU are in Appendix E.

Identification

The soils associated with this LMU have rock or other hard or permanently cemented layer at 30–80cm.

Shallow gravels dominate this LMU, with minor areas of red and pale shallow sands.

Other names

Gravelly sand on laterite

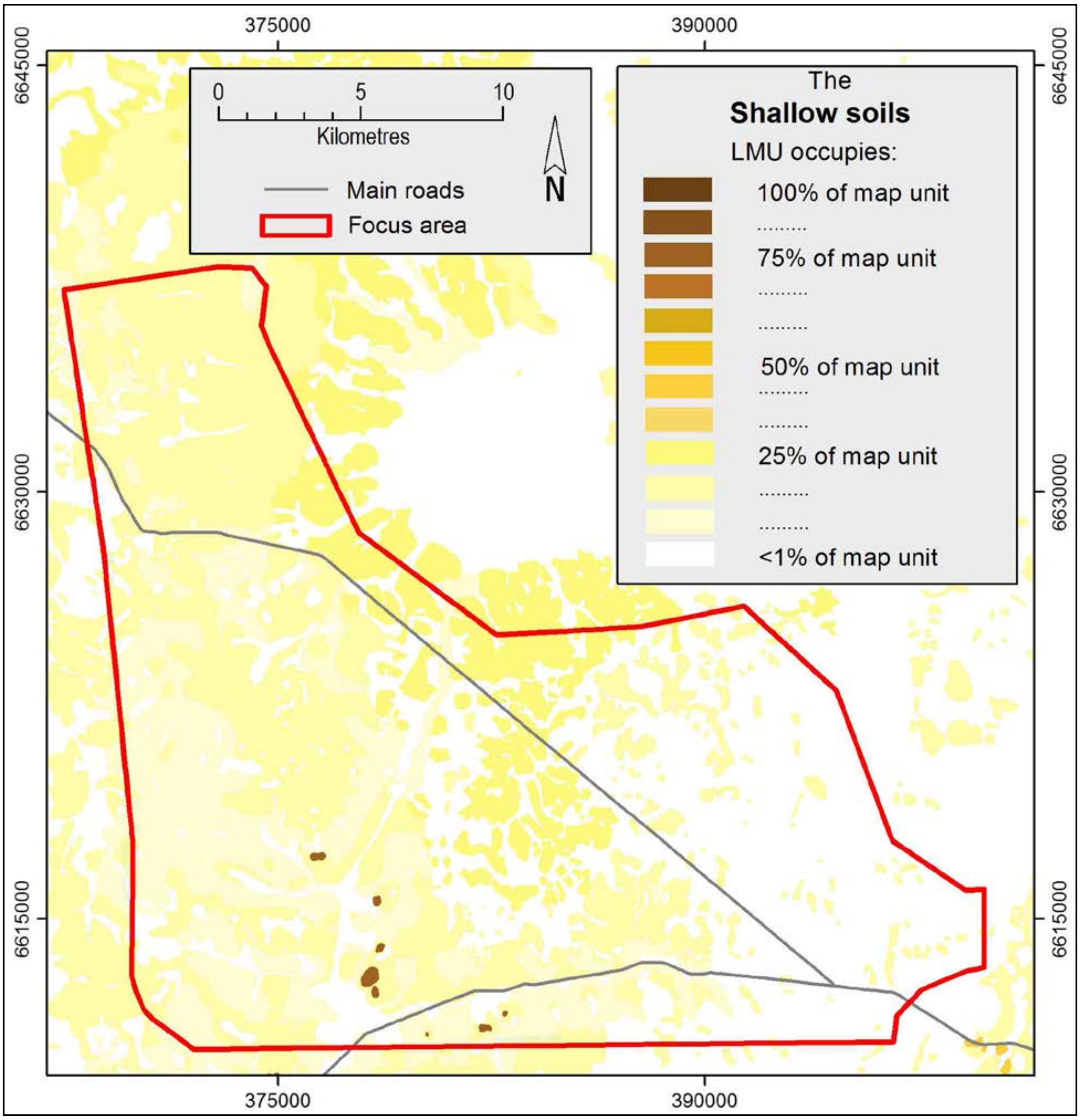
Typical soil profiles of Shallow soils LMU

Management considerations

- This soil's water-holding capacity is generally reduced because of its shallow depth and/or high gravel content.
- Where the hard layer is below 50cm, shallow-rooted crops may be considered with careful application of water and fertiliser.
- Careful monitoring of irrigation is needed to prevent a perched watertable forming and salt concentration developing on the hard layer.
- The risk of wind erosion will necessitate the installation of windbreaks or higher water use to keep topsoils damp.
- The risk of irrigation salinity is low, but salt accumulation may occur in areas of higher evaporation or if water quality is not optimum. Irrigation water will be needed to flush or wash salts from topsoils. Watering will need to be scheduled according to evaporation, crop type and development stage, rather than at set intervals.

Distribution

This is a minor LMU in the Dinner Hill focus area, making up 4% of the soils. It generally occurs on hillcrests and steeper slopes.



Areas of Shallow soils LMU in the Dinner Hill focus area

Potential horticultural crops for Shallow soils LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓
Annual fruits	Strawberries	✓
Root crops	Potatoes, carrots	✗
Pastures/fodder	Clover/ryegrass	✓✓
Nut trees	Almonds	✗
Stone fruit	Peaches	✗
Citrus trees	Mandarins	✗
Other orchard trees	Olives	✗
Vineyard fruit	Table grapes	✗

✓✓ = crop is highly suited; ✓ = crop is suited; ✗ = crop is not suited

Characteristics

Water storage	**Very low**: low clay content and restricted depth; if soil is gravelly, water-holding capacity may be further reduced
Nutrient availability	**Low**: due to low clay content
Rooting conditions	**Moderate**: effective rooting depth generally at 60–80cm; restricted by cemented laterite or other hard layer
Permeability	**Rapid**: may result in excess leaching
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Good to moderate**: gravelly soils may have poorer workability

Land management risks

Nutrient export	**High risk**: very limited capacity to retain nutrients
Irrigation salinity	**Moderate risk**
Soil acidity	**Moderate–high risk**: periodic monitoring is advisable
Soil structure decline	**Moderate risk**: possibility of traffic pan developing in sandy soils; there may be a response to deep-ripping
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Moderate risk**: erosion can be a problem on these soils where slopes are >3%
Wind erosion	**Very high to extreme risk**: soils are sandy and have a loose to soft surface; surface protection is required and windbreaks are necessary

Fair pale sands LMU

Pale sands with loamy sand or clayey sand textures found in the top 30cm. Typical soil profile descriptions of Fair pale sands are presented in Appendix E.

Identification

The soils associated with this LMU are moderate quality pale sands with loamy sand, clayey sand or fine sand texture found in the top 30cm and continuing to beyond 80cm. Subsoil colours frequently become brighter with depth and clay content. Gravels may be present below 15cm. In a few places, the subsoil texture may increase gradually to sandy loam (sandy earth soils).

Pale deep sands dominate this LMU, with minor areas of pale sandy earth and gravelly pale deep sands.

Other names

Pale yellow sand, gutless sand

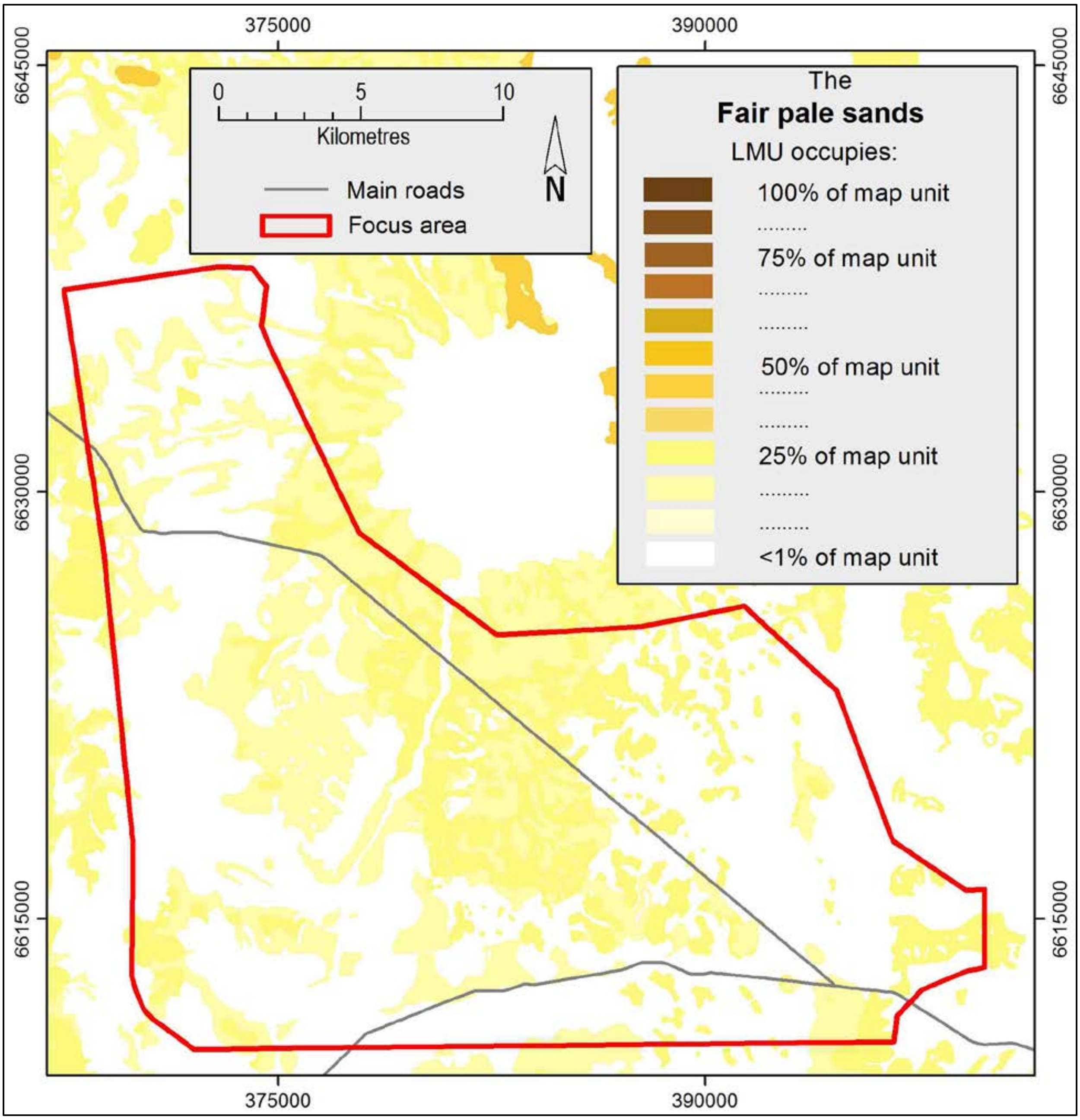
Typical soil profile of Fair pale sands LMU

Management considerations

- This soil is well suited to root crops because of its loose, sandy nature.
- Judicious fertiliser application is essential to maintain fertility.
- Limited water storage and deep drainage of soils require frequent application of relatively small amounts of water.
- The risk of wind erosion will necessitate the installation of windbreaks and higher water use to keep topsoils damp.
- The risk of irrigation salinity is low, but salt accumulation may occur in areas of higher evaporation or if water quality is not optimum. Irrigation water will be needed to flush or wash salts from topsoils. Watering will need to be scheduled according to evaporation, crop type and development stage, rather than at set intervals.

Distribution

Fair pale sands LMU makes up about 4% of the Dinner Hill focus area. It is located mainly on gentler hillslopes and footslopes.



Areas of Fair pale sands LMU in the Dinner Hill focus area

Potential horticultural crops for Fair pale sands LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓
Annual fruits	Strawberries	✓
Root crops	Potatoes, carrots	✓✓
Pastures/fodder	Lucerne	✓
Nut trees	Almonds	✓
Stone fruit	Peaches	✓
Citrus trees	Mandarins	✓
Other orchard trees	Olives	✓
Vineyard fruit	Table grapes	✓

✓✓ = crop is highly suited; ✓ = crop is suited; ✗ = crop is not suited

Characteristics

Water storage	**Low**: low clay and organic matter and greater depth to clayey sand
Nutrient availability	**Low**: due to low clay levels in surface horizons and low nutrient retention; the iron and clay in the sands at greater depth will hold some phosphorous
Rooting conditions	**Good**: loose, sandy topsoil and subsoil provides few barriers to root development
Permeability	**Rapidly drained**: the soils are highly permeable with poor water-holding capacity
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Very good**: workability is very good over a wide moisture range

Land management risks

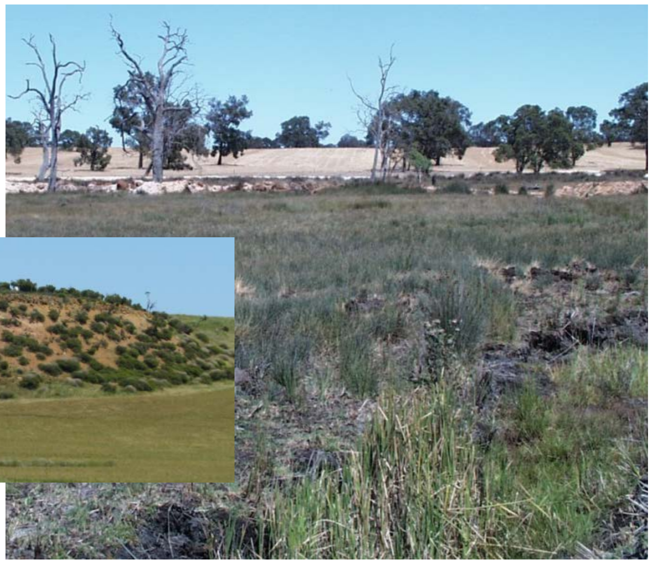
Nutrient export	**High risk**: very limited capacity to retain nutrients
Irrigation salinity	**Low risk**
Soil acidity	**High risk**: regular surface and subsurface monitoring is advisable
Soil structure decline	**Moderate risk**: possibility of traffic pan developing
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Low–moderate risk**: generally rapidly drainage; erosion can be a problem below gravel outcrops and on slopes >3%
Wind erosion	**Very high to extreme risk**: soils are sandy and have a loose to soft surface; surface protection is required and windbreaks are necessary

Unsuitable landforms LMU

Landforms unsuitable for agriculture.

Identification

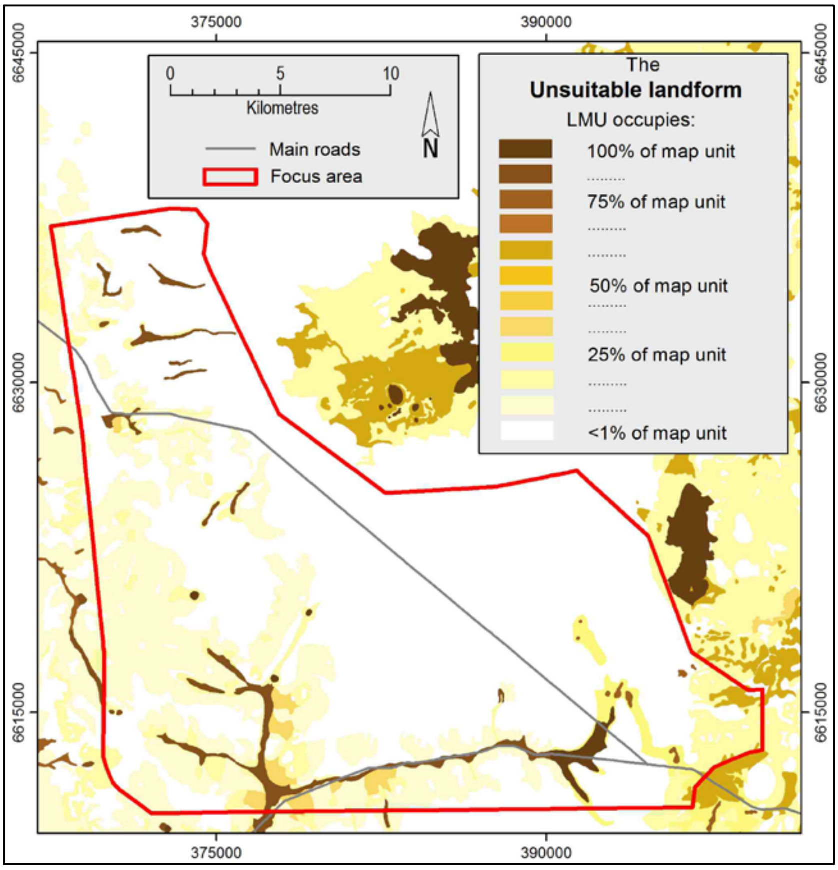
This LMU consists of landforms unsuited for agriculture, including steep (>15%) slopes, waterways, and other wet areas, such as valley depressions and poorly drained flood plains.



Typical types of Unsuitable landforms LMU

Distribution

About 3% of the Dinner Hill focus area is regarded as having a landform unsuitable for agriculture. The greatest concentration of this LMU is found in drainage areas, poorly drained flats and footslope areas.



Areas of Unsuitable landforms LMU in the Dinner Hill focus area

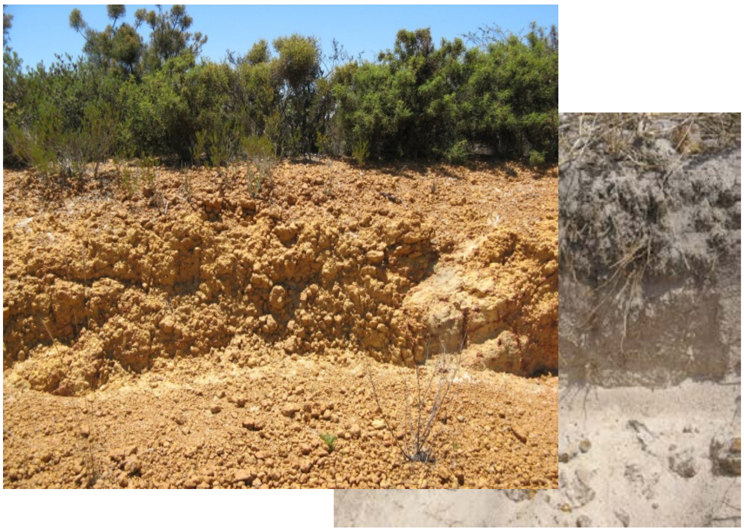
Very shallow or rocky soils LMU

Areas dominated by rock outcrops or shallow soil <30cm over rock or other hard layers. Typical soil profile descriptions of Very shallow or rocky soils LMU are in Appendix E.

Identification

This LMU features areas of rocky outcrops and shallow soil or gravels over rock or other hard layer such as cemented ironstone or limestone at less than 30cm deep.

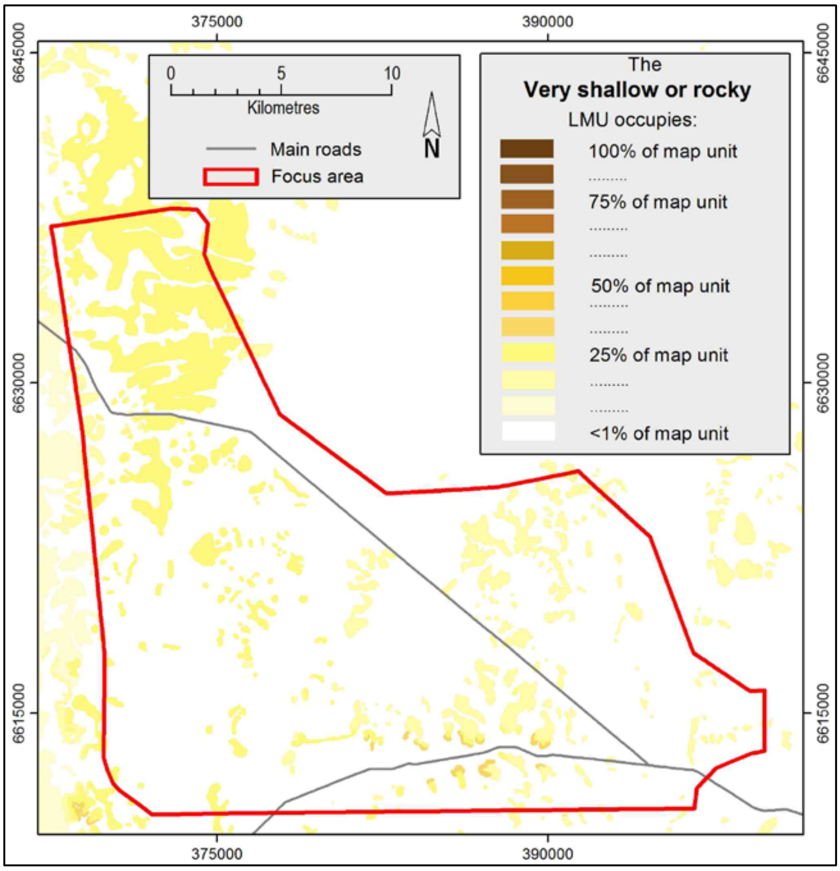
This LMU is mainly shallow gravels and shallow red loams and pale sands.



Typical soil profiles of Very shallow or rocky soils LMU

Distribution

Very shallow or rocky soils LMU is found on about 3% of the Dinner Hill focus area. It is mainly on hill crests and steeper slopes.



Areas of Very shallow or rocky soils LMU in the Dinner Hill focus area

Good loams LMU

Soils with a loamy surface either grading to subsoil clay or over clay subsoil at greater than 15cm with well-drained and/or well-structured and non-sodic subsoil. Typical soil profile descriptions of Good loams LMU are in Appendix E.

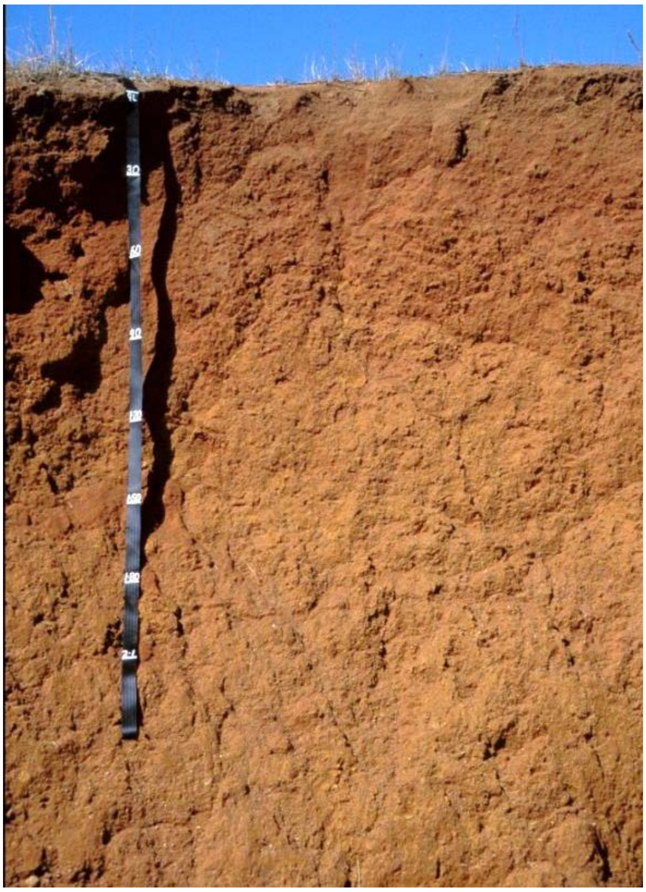
Identification

The soils associated with this LMU are dominated by firm to hardsetting, red and brown loamy earth soils. Minor areas of brown and red loams over clays (deep loamy duplex) are also found.

Red and brown loamy earths dominate this LMU, with minor areas of deep loamy duplex soils.

Other names

Red loam



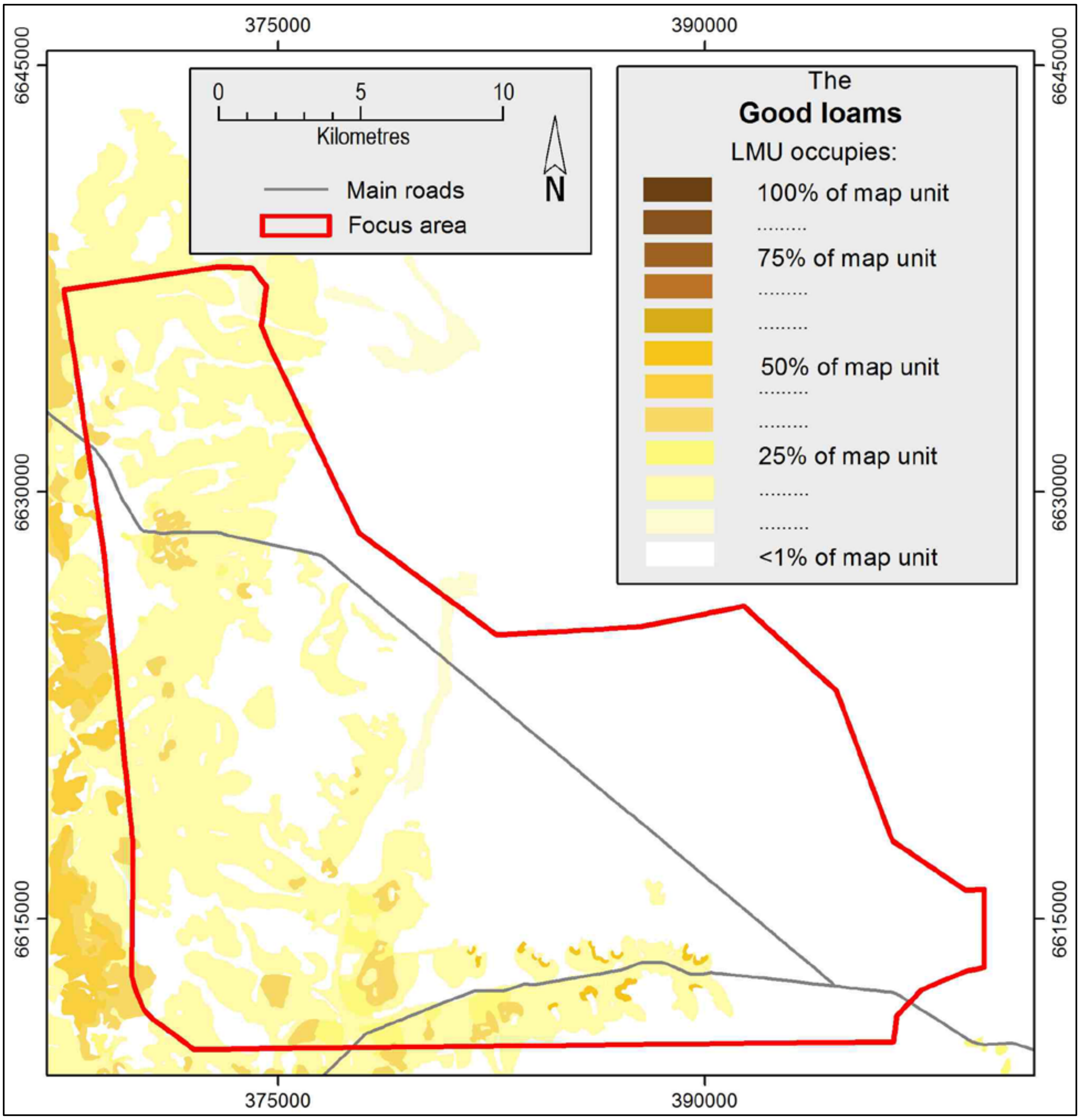
Typical soil profile of Good loams LMU

Management considerations

- The risk of wind erosion will necessitate the installation of windbreaks or higher water use on any unprotected ground to keep topsoils damp.
- This soil may not be well suited to root crops because of its heavier nature.
- There is an extreme soil degradation hazard if water quality is not optimum for irrigation. High levels of salt in heavy soils invariably lead to sodium saturation and the soil becomes sodic. Sodic soil particles readily dissociate or disperse in fresh water (e.g. winter rain) to become structurally unstable.
- Earthworks may be required on lower slopes to prevent water erosion.

Distribution

The Good loams LMU makes up about 2% of the Dinner Hill focus area. It is located mainly on gentle to moderate hillslopes and footslopes.



Areas of Good loams LMU in the Dinner Hill focus area

Potential horticultural crops for Good loams LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓✓
Annual fruits	Strawberries	✓✓
Root crops	Potatoes, carrots	✓
Pastures/fodder	Lucerne	✓✓
Nut trees	Almonds	✓✓
Stone fruit	Peaches	✓✓
Citrus trees	Mandarins	✓✓
Other orchard trees	Olives	✓✓
Vineyard fruit	Table grapes	✓✓

✓✓ = crop is highly suited; ✓ = crop is suited; ✗ = crop is not suited

Characteristics

Water storage	**Moderate to good**: storage depends on texture; sandier soils have more moderate water storage capacity
Nutrient availability	**Good**: retention of applied fertiliser is fair to good, depending on the soil texture and organic matter
Rooting conditions	**Good**: no obvious barriers as the soil is porous and permeable; may not suit growth of all root vegetables
Permeability	**Moderately well drained**: isolated areas with higher clay content may be waterlogged
Trafficability	**Generally good**
Soil workability	**Good**: workability is good over a wide moisture range

Land management risks

Nutrient export	**Low risk**: good nutrient retention
Irrigation salinity	**High risk**: the quality of irrigation water needs to be optimum
Soil acidity	**Moderate risk**: periodic monitoring is advisable
Soil structure decline	**Moderate–high risk**: excess working at too high or too low moisture levels or high speed and reduced organic matter may lead to degraded structure and a surface seal; quality of irrigation water needs to be optimum
Water repellence	**Low risk**
Water erosion	**Moderate risk**: erosion can be a problem on these soils where slopes are >3%
Wind erosion	**Moderate risk**: maintenance of surface protection is required and windbreaks are necessary to protect topsoil

Poor gravels LMU

Gravels with a coarse or gritty sandy matrix and/or with abundant (>70%) gravel content. Typical soil profile descriptions of Poor gravels LMU are in Appendix E.

Identification

This LMU features areas of deep, sandy gravels which have a coarse sandy matrix and frequently have a high gravel content (>70%).

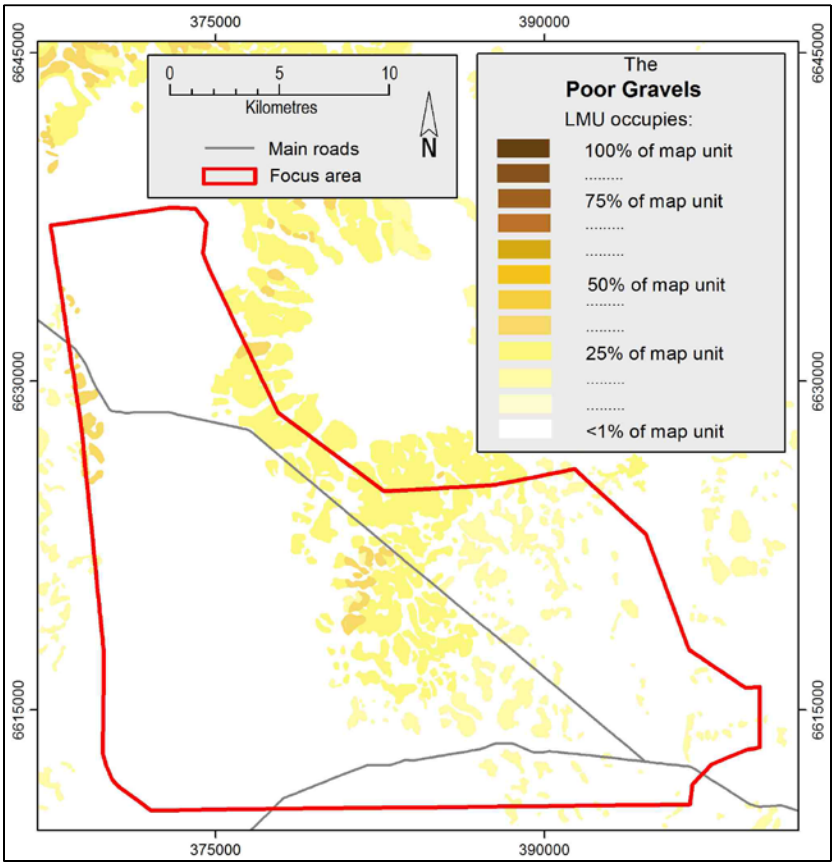
These poor gravels are generally found on hill crests and gentle to moderate hillslopes. They have very low water-holding capacity.

The soils of this LMU are mainly Deep sandy gravels.

Typical soil profile of Poor gravels LMU

Distribution

Poor gravels are found in about 2% of the Dinner Hill area, mainly on hillcrests and steeper slopes.



Areas of Poor Gravels LMU in the Dinner Hill focus area

Good sandy duplexes LMU

Soils with a sandy surface over a well-structured, non-sodic clay layer at 30–80cm. Typical soil profile descriptions of Good sandy duplex LMU are in Appendix E.

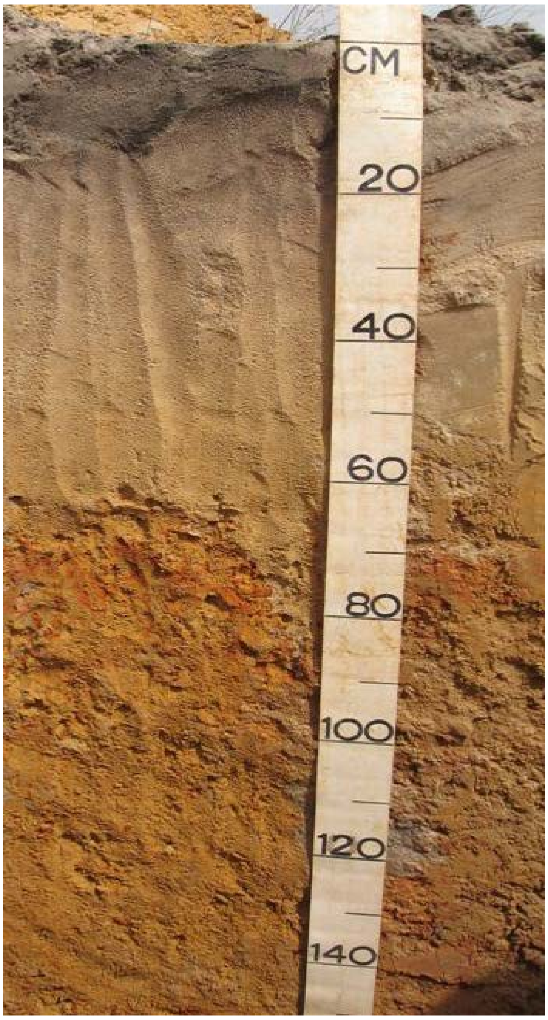
Identification

The soils associated with this LMU are dominated by yellow/brown loamy or clayey sands over a well-structured or permeable non-sodic clay layer at 30–80cm. Topsoils may have a darker staining of organic matter.

These soils are generally yellow/brown or red sandy topsoils over good clay subsoils.

Other names

Sand over clay, Sandy duplex



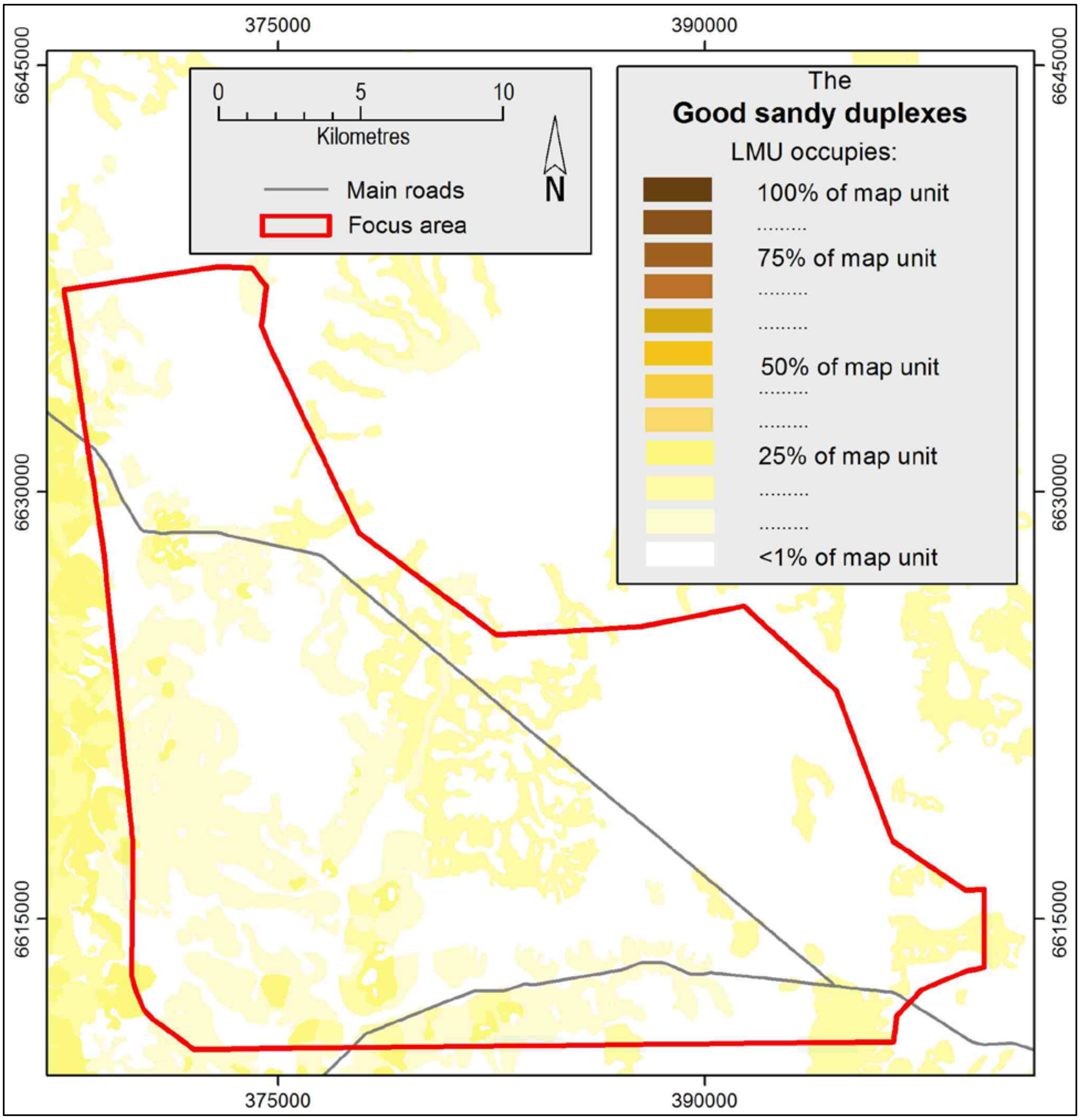
Typical soil profile of Good sandy duplexes LMU

Management considerations

- This soil is marginally suited to root crops if the clay layer is below 50cm.
- The risk of wind erosion will necessitate the installation of windbreaks or higher water use to keep topsoils damp.
- Careful monitoring of irrigation is required to prevent a perched watertable forming above the clay layer and an increase in salt concentration.
- The risk of irrigation salinity is low, but salt accumulation may occur in areas of higher evaporation or if water quality is not optimum. Irrigation water will be needed to flush or wash salts from topsoils. Watering will need to be scheduled according to evaporation, crop type and development stage, rather than at set intervals.

Distribution

This is a minor LMU, making up about 1% of the soils in the Dinner Hill focus area. It generally occurs on hillslopes, mainly to the west of Dandaragan.



Areas of Good sandy duplexes LMU in the Dinner Hill focus area

Potential horticultural crops for Good sandy duplexes LMU

Potential crop	Examples	Suitability
Annual shallow-rooted vegetables	Leeks	✓✓
Annual fruits	Strawberries	✓✓
Root crops	Potatoes, carrots	✓
Pastures/fodder	Lucerne	✓✓
Nut trees	Almonds	✓✓
Stone fruit	Peaches	✓✓
Citrus trees	Mandarins	✓✓
Other orchard trees	Olives	✓✓
Vineyard fruit	Table grapes	✓✓

✓✓ = crop is highly suited; ✓ = crop is suited; × = crop is not suited

Characteristics

Water storage	**Poor**: storage is poor in sandy layers above clay
Nutrient availability	**Low**: sandy surface horizons have low fertility and high leaching losses
Rooting conditions	**Good to moderate**: rooting depth is restricted by clay
Permeability	**Good to moderate**: drainage is generally good in most locations, but may be lower in depressions and clay may restrict downward water movement
Trafficability	**Generally good**: it is possible to get bogged in dry sand in summer
Soil workability	**Very good**: workability is very good over a wide moisture range

Land management risks

Nutrient export	**Moderate risk**: sandy topsoils have a high risk, but subsoil clays improve nutrient retention
Irrigation salinity	**Moderate risk**: careful monitoring of irrigation is required to ensure salt is not increasing above the clay layer
Soil acidity	**High risk**: periodic monitoring is advisable
Soil structure decline	**Moderate–high risk**: possibility of traffic pan developing
Water repellence	**Moderate risk**: risk is reduced with regular wetting and cultivation of topsoil for annuals; if soil dries, risk is high
Water erosion	**Moderate risk**: erosion can be a problem on these soils on slopes >3%
Wind erosion	**Very high to extreme risk**: surface soils are sandy and have a loose to soft surface; surface protection is required in summer and autumn and windbreaks are necessary

Appendixes

A Land capability assessment

B Soil-landscape map unit descriptions

C Chemistry of deep sands

D Down-hole logging of bores

E LMUs and soil profiles

F Distribution of LMUs in soil-landscape subsystems

Appendix A Land capability assessment

A1 Land quality codes used in ratings tables

Table A1 presents the land quality value codes used in the ratings tables for annual and perennial horticulture (Table A2.1 and Table A2.2, respectively) along with a brief definition of each code. See van Gool et al. (2005) for more-detailed definitions of these land qualities and their value codes, except for inherent fertility (see Tille et al. 2013) and irrigation salinity hazard (see Table A1).

Table A1 Land quality value codes used in the capability ratings tables

Land quality	Value codes
Flood hazard	N (nil), L (low), M (moderate), H (high)
Inherent fertility	VH (very high), H (high), M (moderate), L (low), VL (very low)
Irrigation salinity hazard	VL (very low), L (low), M (moderate), MH (moderately high), H (high), VH (very high)
Land instability hazard	N (nil), VL (very low), L (low), M (moderate), H (high)
pH 0–10cm, pH 15–25cm, pH 50–80cm (pH in $CaCl_2$)	**VSac** (very strongly acid: <5.3), **Sac** (strongly acid: 5.3–5.6), **Mac** (moderately acid: 5.6–6), **Slac** (slightly acid: 6–6.5), N (neutral: 6.5–8), **Malk** (moderately alkaline: 8–9), **Salk** (strongly alkaline: >9)
Phosphorus export risk	L (low), M (moderate), H (high), VH (very high), E (extreme)
Rooting depth (cm)	VS (<15), S (15–30), MS (30–50), M (50–80), D (>80), VD (>150)
Salinity hazard	NR (none), PR (partial or low), MR (moderate), HR (high), PS (saline land)
Salt spray exposure	S (susceptible), N (not susceptible)
Site drainage potential	R (rapid), W (well), MW (moderately well), M (moderate), P (poor), VP (very poor)
Soil water storage 0–100cm (mm of available water)	EL (extremely low: <30), VL (very low: 30–50), L (low: 50–70), ML (moderately low: 70–100), M (moderate: 100–130), H (high: >130)
Soil water storage 0–50cm (mm of available water)	EL (extremely low: <15), VL (very low: 15–25), L (low: 25–35), ML (moderately low: 35–50), M (moderate: 50–65), H (high: >65)
Soil workability	G (good), F (fair), P (poor), VP (very poor)
Subsurface compaction susceptibility	L (low), M (moderate), H (high)
Surface salinity	N (nil), S, (slight), M (moderate), H (high), E (extreme)
Surface soil structure decline susceptibility	L (low), M (moderate), H (high)
Trafficability	G (good), F (fair), P (poor), VP (very poor)
Water erosion hazard	VL (very low), L (low), M (moderate), H (high), VH (very high), E (extreme)
Waterlogging / inundation risk	N (nil), VL (very low), L (low), M (moderate), H (high), VH (very high)
Water repellence	N (nil), L (low), M (moderate), H (high)
Water repellence susceptibility	N (nil), L (low), M (moderate), H (high)
Wind erosion hazard	L (low), M (moderate), H (high), VH (very high), E (extreme)

Sources: van Gool et al. (2005), Tille et al. (2013)

A2 Land capability ratings tables

Table A2.1 presents the ratings table used to assess land capability for annual horticulture and Table A2.2 presents the ratings table used to assess land capability for perennial horticulture.

Table A2.1 Capability ratings table for annual horticulture

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L	M		H
Inherent fertility	H, VH, M	L	VL		
Irrigation salinity hazard	VL, L	M, MH	H	VH	
Land instability hazard	N, VL, L		M	H	
pH at 0–10cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 15–25cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
pH at 50–80cm	Slac, N	Sac, Mac, Malk	Vsac, Salk		
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD, D	M	MS	S	VS
Salinity hazard	NR	PR		MR, HR	PS
Salt spray exposure	N			S	
Soil water storage 0–100cm	H, M, ML	L, VL	EL		
Soil water storage 0–50cm	H, M, ML	L	VL	EL	
Soil workability	G	F		P	VP
Subsurface compaction susceptibility	N	H			
Surface salinity	N		S	M	H, E
Surface soil structure decline	L, M	H			
Trafficability	G	F		P	VP
Water erosion hazard	VL	L	M	H, VH	E
Waterlogging / inundation risk	N, VL	L	M	H	VH
Water repellence susceptibility	N, L, M	H			
Wind erosion risk	L, M	H	VH		E

Adapted from: van Gool et al. (2005)

Table A2.2 Capability ratings table for perennial horticulture

Land quality	Class 1	Class 2	Class 3	Class 4	Class 5
Flood hazard	N	L		M	H
Inherent fertility	H, VH, M	L	VL		
Irrigation salinity hazard	VL, L	M, MH	H		VH
Land instability hazard	N, VL, L		M		H
pH at 0–10cm	Slac, N	Mac	Vsac, Sac, Malk, Salk		
pH at 50–80cm	Slac, N	Mac, Malk	Vsac, Sac, Salk		
Phosphorus export risk	L, M	H	VH	E	
Rooting depth	VD, D		M	MS	S, VS
Salinity hazard	NR		PR	MR	HR, PS
Salt spray exposure	N			S	
Soil water storage 0–100cm	H, M, ML	L	VL	EL	
Soil water storage 0–50cm	H, M, ML, L	VL, EL			
Soil workability	G	F	P	VP	
Subsurface compaction susceptibility	L, M	H			
Surface salinity	N		S	M	H, E
Trafficability	G	F		P	VP
Water erosion hazard	VL, L	M, H		VH	E
Waterlogging / inundation risk	N, VL		L	M	H, VH
Water repellence susceptibility	N, L, M	H			
Wind erosion risk	L, M	H, VH		E	

Adapted from: van Gool et al. (2005)

A3 Example of proportional map unit capability ratings

Table A3.1 Proportional attribution of soils and landforms, and capability ratings for map unit Rowes 3 subsystem, typical phase (222Rw3a) in the Dinner Hill focus area

WA Soil Group	Qualifier[a]	Landscape[a]	Map unit proportion (%)	Capability class for annual horticulture	Capability class for perennial horticulture
Yellow deep sand	fair sand, very deep	slopes 1–3%	40	Class 3	Class 3
Yellow deep sand	poor sand, very deep	slopes 1–3%	20	Class 4	Class 4
Yellow deep sand	good sand, very deep	slopes 1–3%	10	Class 2	Class 2
Deep sandy gravel	good sand, very deep	crests & slopes <3%	8	Class 3	Class 2
Duplex sandy gravel	neutral subsoil	crests & slopes <3%	5	Class 3	Class 2
Duplex sandy gravel	neutral subsoil	slopes 3–5%	5	Class 3	Class 2
Pale deep sand	poor sand, very deep	crests & slopes <3%	5	Class 4	Class 4
Yellow sandy earth	good neutral subsoil	slopes 1–3%	5	Class 3	Class 2
Gravelly pale deep sand	poor sand, effective duplex	crests & slopes <3%	2	Class 3	Class 3

a For more details and definitions of qualifiers and landscapes, see van Gool et al. (2005)

Table A3.2 Proportional attribution of capability ratings for map unit Rowes 3 subsystem, typical phase (222Rw3a) (taken from Table A3.1)

Land use	Percentage of classes 1 & 2 (%)	Percentage of Class 3 (%)	Percentage of classes 4 & 5 (%)	Map unit capability code[a]
Annual horticulture	10	65	25	B1
Perennial horticulture	33	42	25	B1

a See Table 2.2 for a description of the map unit capability codes.

Appendix B Soil-landscape map unit descriptions

Table B1 Soil-landscape descriptions for subsystems and phases in the Dinner Hill focus area

Soil-landscape subsystem	Code	Description	Area (ha)	Area (%)
Dandaragan Plateau Zone (222)				
Agaton 1 plain phase	222Ag_1c	Alluvial plain of lunettes and small playas, commonly saline. Saline wet soil, sandy duplexes (often alkaline), sandy earths on pans	34	<1
Agaton 5 low dunes phase	222Ag_5a	Low to very low dunes with broad crests plus swales and some flats. Yellow and pale sands	454	<1
Agaton 5 damp swales phase	222Ag_5d	Swales, open and closed depressions, commonly waterlogged. Wet soil, pale and yellow sands, sandy duplexes (some alkaline), sandy earths	156	<1
Coalara 1 subsystem	222Co_1	Quaternary valley plain, low dunes common. Pale and yellow deep sands, some playa soils	363	<1
Coalara 3 crests phase	222Co_3a	Plateau residue and hillslopes, and some small breakaways. Sandy gravels, gravelly pale deep sand	470	<1
Coalara 3 breakaway phase	222Co_3c	Gently to moderately inclined minor breakaway slopes. Sandy gravels, sandy duplexes (over pallid zone clays)	57	<1
Coalara 5 plain phase	222Co_5a	Plain, hillcrests and very gently inclined hillslopes. Pale sandy gravels, gravelly pale deep sand, pale and yellow deep sands	3877	8
Coalara 6 valley slope phase	222Co_6a	Very gently to gently inclined hillslopes and minor sand-filled drainage lines. Yellow and pale deep sands	3446	7
Coalara 6 colluvial phase	222Co_6b	Gently inclined slope below scarp. Yellow deep sand, sandy duplexes	47	<1
Coalara 6 minor valley phase	222Co_6c	Flat to very gently inclined slopes of very minor sand-filled drainage lines within plain. Pale and yellow sands	111	<1
Capitella 1 sandy gravel phase	222Cp_1a	Hillcrests and very gently inclined upper hillslopes. Sandy gravels, gravelly pale deep sand and pale sands	109	<1
Capitella 2 yellow phase	222Cp_2a	Very gently to gently inclined hillslopes, sandplain and minor valleys, associated with 222Cp_1a. Yellow and pale deep sands, gravelly pale deep sand, some sandy earths	640	1
Capitella 4 York gum phase	222Cp_4b	Very gently inclined hillcrests. Brown sandy earths and Yellow deep sand, gravels	17	<1

(continued)

Table B1 continued

Soil-landscape subsystem	Code	Description	Area (ha)	Area (%)
Capitella 5 plain phase	222Cp_5c	Broad sand-filled open depressions with very low dunes. Yellow and pale deep sands	2175	4
Capitella 6 low dunes phase	222Cp_6a	Alluvial plain with very low dunes. Pale and yellow deep sands	675	1
Capitella 6 wet phase	222Cp_6c	Open and closed depressions within 222Cp_6a, frequently waterlogged and inundated. Wet soil, pale sands, sandy duplexes	49	<1
Capitella 7 diatomite phase	222Cp_7d	Diatomite small playas. Shallow loam over diatomite or pans, wet soil	267	<1
Dandaragan 1 crest phase	222Da_1a	Hillcrests and very gently to gently inclined hillslopes. Red to pale sandy gravels, shallow red to pale sands over duricrust, some red to yellow deep sands	894	2
Dandaragan 1 small crest phase	222Da_1b	Small hillcrests associated with rejuvenation. Loamy gravel, loamy earths, duplex sandy gravel	52	<1
Dandaragan 1 stripped slope phase	222Da_1c	Gently to moderately inclined small breakaway slopes. Red sandy and loamy gravels	88	<1
Dandaragan 1 plateau phase	222Da_1d	Plateau remnant, plain with some hillcrests. Shallow red to brown sands over gravel and duricrust, red sandy gravels	4154	8
Dandaragan 1 pale phase	222Da_1e	Hillcrests and some very gently inclined hillslope. Pale sandy gravels, pale sand over duricrust	117	<1
Dandaragan 2 yellow phase	222Da_2a	Very gently to gently inclined hillslopes, some hillcrests and plateau remnants. Yellow and brown deep sands, some sandy earths	7363	15
Dandaragan 2 pale phase	222Da_2b	Hillcrests and very gently to gently inclined upper hillslopes. Pale and yellow deep sands, gravelly pale deep sand	655	1
Dandaragan 3 subsystem	222Da_3	Colluvial slopes, very gently to gently inclined hillslopes. Red to brown and yellow deep sands, some sandy gravels and sandy earths	9970	20
Dandaragan 4 slopes phase	222Da_4a	Very gently to gently inclined upper hillslopes, partially stripped. Very variable, loamy and sandy duplexes, loamy earths, red deep sand, loamy gravel	818	2
Dandaragan 4 breakaway phase	222Da_4b	Gently to moderately inclined upper hillslopes, minor breakaway slopes. Variable, loamy duplexes, loamy gravel, red deep sand	34	<1
Dandaragan 5 subsystem	222Da_5	Stripped slopes, very gently inclined hillslopes and hillcrests. Shallow calcareous loams	64	<1

(continued)

Table B1 continued

Soil-landscape subsystem	Code	Description	Area (ha)	Area (%)
Dandaragan 6 subsystem	222Da_6	Fans, very gently inclined footslopes and hillslopes, derived from stripping of 222Da_4 and 222Da_5. Sandy duplexes, loamy earths, red deep sand, some sandy gravels	567	1
Dandaragan 7 dry phase	222Da_7a	Very gently inclined footslopes and open depressions. Pale and yellow deep sands, sandy duplexes	747	1
Dandaragan 7 wet phase	222Da_7b	Narrow open depressions. Wet soil, sandy and loamy duplexes, deep sands	368	<1
Dandaragan 8 typical phase	222Da_8a	Alluvial plain and sand-filled open depressions. Wet soil, sandy and loamy duplexes (often over pan or bog iron), pale deep sand, shallow loams on pans	515	1
Dandaragan 9 subsystem	222Da_9	Playas. Shallow sands and loams over pans, often wet soil	22	<1
Rowes 1 typical phase	222Rw_1a	Plateau residuals, sand plain. Yellow deep sand, some sandy earths and gravelly pale deep sand	865	2
Rowes 1 pale phase	222Rw_1b	Sandplain, some hillcrest. Yellow deep sand, sandy earths, sandy gravels	1007	2
Rowes 2 subsystem	222Rw_2	Plateau residuals, hillcrests and very gently to gently inclined hillslopes. Sandy gravels, gravelly pale deep sand, some duricrust	2051	4
Rowes 3 typical phase	222Rw_3a	Colluvial slopes, very gently to gently inclined hillslopes and sand filled minor valleys. Mainly yellow deep sand	6909	14
Arrowsmith Zone (224)				
Boothendarra 3 subsystem	224Bh_3	Residuals, low hillcrests and hillslopes. Sandy and loamy gravels, sandy duplexes	22	<1
Boothendarra 4 subsystem	224Bh_4	Gently to very gently inclined hillslopes and footslopes. Sandy duplexes, deep sands and sandy gravels	1	<1
Boothendarra 5 subsystem	224Bh_5	Residuals, gently to very gently inclined hillslopes, often gilgai. Loamy earths, loamy duplexes, some sandy duplexes and clays	1	<1

Appendix C Chemistry of deep sands

These samples were collected in the focus area using an auger drill rig.

Table C1 Chemistry of deep sands

WA Soil Group[a]	Site (WM)	Depth (cm)	Texture	Clay (%)	Silt (%)	Silt / clay[b]	Sand <200µ (%)	CF (%)	EC	pH	P_HCO$_3$	K_HCO$_3$	B_CaCl$_2$	CEC	ESP
441	230	0–10	S	7	0		93	1	7	5.1	29	104	0.5	2.9	4
	230	10–100	MS	6[c]				0	1	4.8	8	19	0.2	0.3	3
	230	200–300	MS	10	0		94	0	1	5.6	5	20	0.2	0.7	4
	230	600–700	S	29	3	0.1	87	13	3	5.1	17	59	0.3	3.2	2
	230	900–1000	MC	50	5	0.1	66	14	7	5	265	205	1	7.5	13
441	233	0–10	S	5[c]				1	22	6.5	23	105	0.5	8.1	9
	233	50–70	S	5[c]				0	1	5.6	2	16	0.2	1.1	4
	233	200–300	S	5[c]				0	1	6.5	1	7.5	0.2	0.9	5
	233	600–700	SCL	25[c]				10	2	6.3	1	47	0.5	4.0	16
	233	800–900	SLMC	42[c]				8	3	6.4	1	105	1.0	6.6	25
444	229	0–10	S	3[c]				2	13	5.3	31	137			
	229	50–70	S	3[c]				0	1	4.5	11	46			
	229	200–300	MS	3[c]				0	1	5.7	3	7.5			
	229	600–700	S	3[c]				0	5	5.8	2	7.5			
	229	900–1000	S	3[c]				0	6	5.8	1	7.5			
444	231	0–10	S	3[c]				1	2	6	72	69			
	231	10–100	S	3[c]				42	1	4.8	365	65			
	231	300–400	FS	3[c]				2	2	5.8	60	7.5			
	231	500–600	FS	3[c]				3	4	5.4	81	7.5			
445	227	0–10	KS	6	0		98	2	6	6.8	29	84	0.2	3.3	2
	227	10–50	MS	6[c]				0	2	4.9	2	16	0.2	0.4	6
	227	200–300	MS	9	1		97	0	1	6.2	1	15	0.2	0.5	6
	227	600–700	KS	7	2		95	8	1	6.1	1	7.5	0.1	0.2	10
	227	900–1000	KS	5	1		97	2	1	6.3	1	7.5	0.1	0.1	17
445	228	0–10	S	3[c]				2	8	5.7	20	131			
	228	50–70	S	3[c]				0	1	5.5	4	20			
	228	200–300	S	3[c]				29	1	6	2	7.5			
	228	600–700	S	3[c]				2	1	5.9	1	7.5			
	228	900–1000	SC	40[c]				3	3	6	1	38			

(continued)

Table C1 continued

WA Soil Group[a]	Site (WM)	Depth (cm)	Texture	Clay (%)	Silt (%)	Silt / clay[b]	Sand <200µ (%)	CF (%)	EC	pH	P_HCO$_3$	K_HCO$_3$	B_CaCl$_2$	CEC	ESP
445	232	0–10	S	10	3		92	3	12	6.1	40	310	0.6	8.1	5
	232	50–70	S	8[c]				2	2	5.5	3	115	0.3	1.4	7
	232	200–300	S	16	3	0.2	88	25	4	5.8	6	58	0.4	3.0	7
	232	300–400	S	8[c]				28	2	6.3	12	81	0.3	2.6	6
	232	600–700	C	50[c]				0	27	3.9	113	430	1.8	23.3	18
445	234	0–10	S	5[c]				2	36	6.7	20	419	0.8	8.3	13
	234	100–200	S	5[c]				0	1	6.2	1	22	0.2	0.8	4
	234	400–500	S	5[c]				0	2	6.5	1	7.5	0.2	0.7	6
	234	800–900	S	5[c]				26	2	6.1	1	22	0.3	1.0	25

a WA Soil Group codes: 441 = Brown deep sand, 444 = Pale deep sand, 445 = Red deep sand,

b Only calculated where clay was more than 15%.

c The percentage of clay was inferred from texture.

Note: Table C2 explains the texture and chemistry methods codes

Table C2 Definition of texture and chemistry methods codes

Code	Texture description	Code	Chemistry method
C	Light clay, 31–45% clay	CF%	% coarse fragments in whole soil
CFS	Clayey fine sand, 5–10% clay	clay	% clay in fine earth
CKS	Clayey coarse sand, 5–10% clay	silt	% silt in fine earth
CL	Clay loam, 30–35% clay	sand	% sand in fine earth
CLKS	Clay loam, coarse sandy, 30–35% clay	pH	pH 1:5 (in calcium chloride) in fine earth
CLS	Clay loam, sandy, 30–35% clay	Al_$CaCl_2$	Extractable aluminium (in calcium chloride) in fine earth
CS	Clayey sand, 5–10% clay	EC	Electrical conductivity (1:5) in fine earth
FS	Fine sand	OC_wb	Organic carbon Walkley & Black method in fine earth
FSCL	Fine sandy clay loam, 18–31% clay	B_$CaCl_2$	Extractable boron (in calcium chloride) in fine earth
FSL	Fine sandy loam, 10–20% clay	K_HCO_3	Extractable potassium (in bicarbonate) in fine earth
GR	Gravel, >60% coarse fragments, gravel dominant	P_HCO_3	Extractable phosphorus (in bicarbonate) in fine earth
KS	Coarse sand	P_kjel	Extractable phosphorus in fine earth
KSCL	Coarse sandy clay loam, 18–31% clay	PRI	Phosphorus retention index of fine earth
KSL	Coarse sandy loam, 10–20% clay	CEC	Cation exchange capacity in fine earth
KSLC	Coarse sandy light clay, 35–40% clay	Exch_Ca	Exchangeable calcium in fine earth
KSLMC	Coarse sandy light medium clay, 40–45% clay	Exch_K	Exchangeable potassium in fine earth
L	Loam, ~25% clay	Exch_Mg	Exchangeable magnesium in fine earth
LC	Light clay, 35–40% clay	Exch_Na	Exchangeable sodium in fine earth
LFS	Loamy fine sand, ~5% clay	ESP	Exchangeable sodium percentage in fine earth
LMC	Light medium clay, 40–45% clay	Exch_Al	Exchangeable aluminium in fine earth
LS	Loamy sand, ~5% clay		
MC	Medium clay, 45–55% clay		
MS	Medium sand		
MSLC	Medium sandy light clay, 35–40% clay		
S	Sand		
SC	Sandy clay, 35–50% clay		
SCL	Sandy clay loam, 18–31% clay		
SL	Sandy loam, 10–20% clay		
SLC	Sandy light clay, 35–40% clay		
SLMC	Sandy light medium clay, 40–45% clay		
VWCMS	(Very weak) clayey medium sand with 1–3% clay		
WCFS	(Weak) clayey fine sand with 3–5% clay		
WCKS	(Weak) clayey coarse sand with 3–5% clay		

Appendix D Down-hole logging of bores

Three of the drilled bores were logged to provide electromagnetic and gamma readings (Figures D1 to D3). Note that the charts have different scales on their horizontal axes. Figure 2.2 shows the location of the bore sites. Appendix C has the soil texture and limited chemistry of these sites.

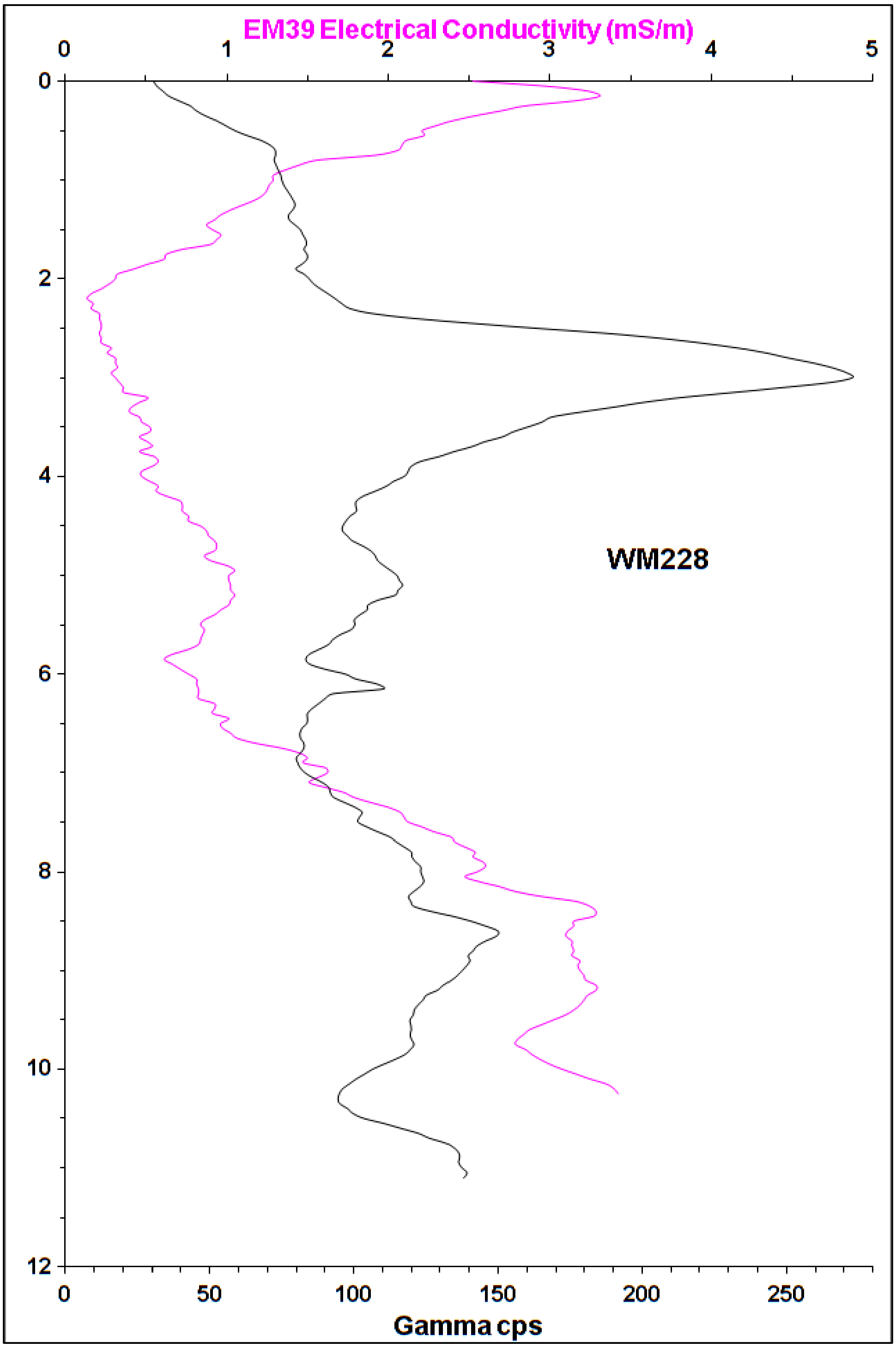


Figure D1 Electromagnetic and gamma readings at site WM228 (GDA94 zone 50, 372844mE, 6612975mN; sand to 9m over sandy clay; gravel at 2.5m; wet at 11m)

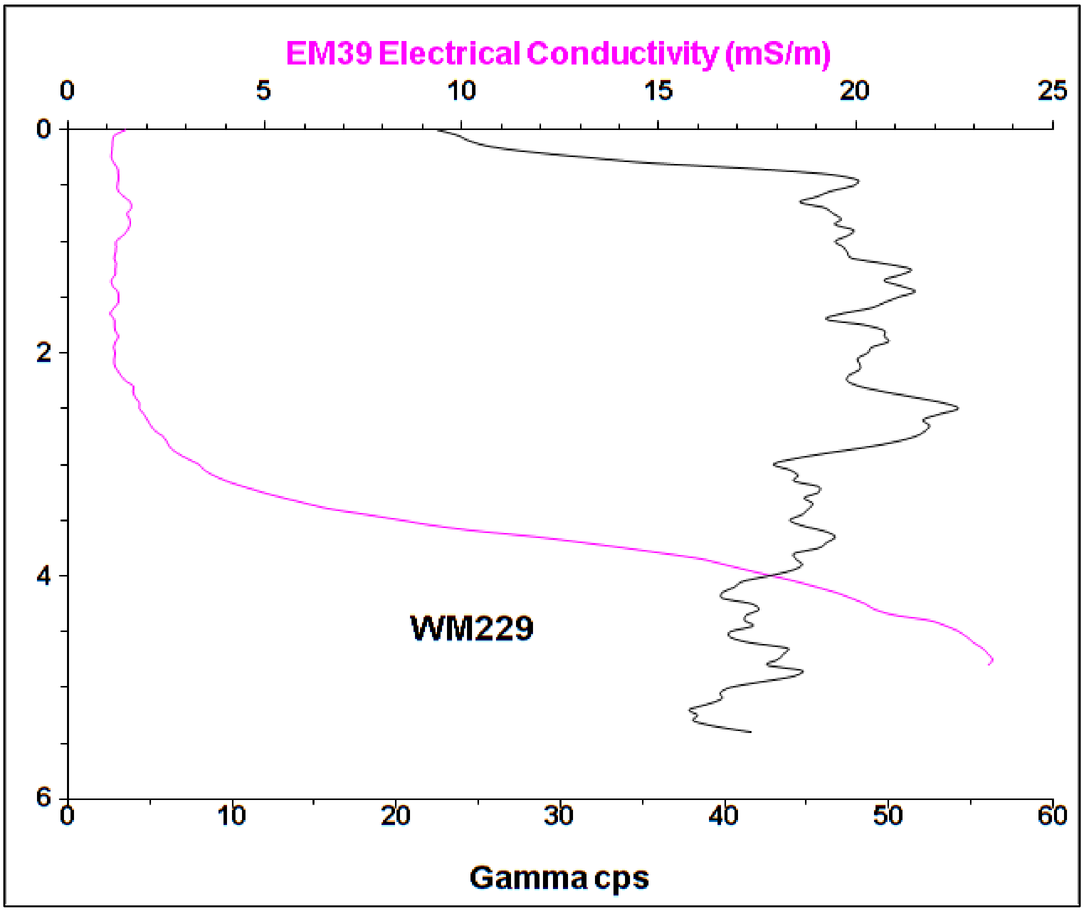


Figure D2 Electromagnetic and gamma readings at site WM229 (GDA94 zone 50, 372917mE, 6613531mN; sand to 11m over gleyed clay; saturated at 3m; hard iron pan 6.5–8m)

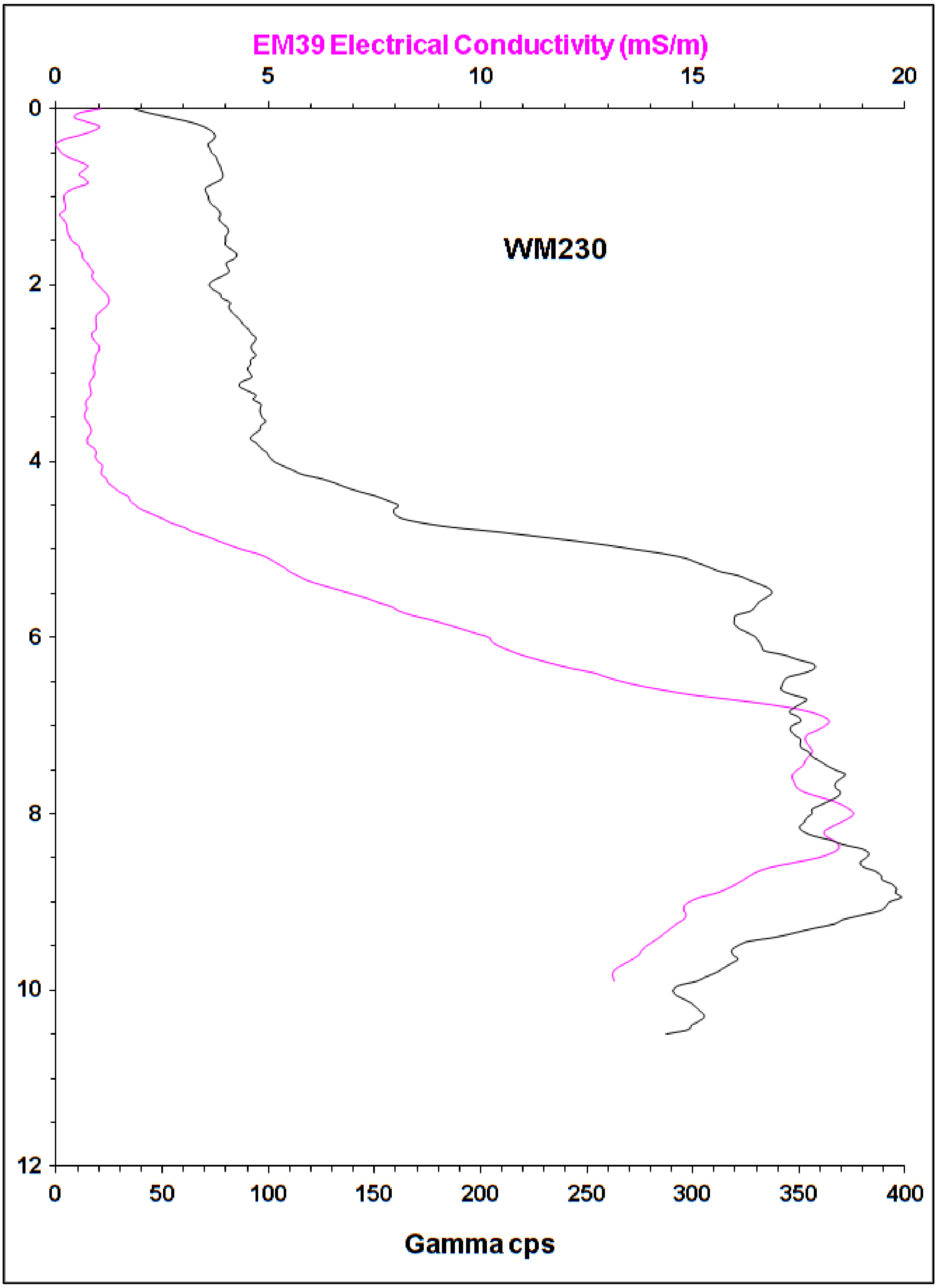


Figure D3 Electromagnetic and gamma readings at site WM230 (GDA94 zone 50, 373546mE, 6617249mN; sand to 6m over iron-rich medium clay saprolite; gravel 4.5–6m)

Appendix E LMUs and soil profiles

The following tables are representative soil profiles, along with soil chemistry (where available), for typical WA Soil Groups found in the main LMUs suited for irrigated agriculture. Table 6.1 lists all the LMUs in order. As far as possible, the profiles are from a location within, or close to, the Dinner Hill focus area.

The codes for texture and chemistry methods are defined in Table C2 in Appendix C.

Good coloured sands LMU (21% of focus area)

WA Soil Groups in LMU	Percentage of LMU (%)
Red deep sand	45
Yellow deep sand	20
Brown deep sand	15
Yellow sandy earth	10
Red sandy earth	5

Red deep sand

Representative site 1: WM0232

WA Soil Group:	Red deep sand
Qualifier:	GSV (Good sand, very deep: clayey or loamy sand dominates the profile and occurs within 30cm of the surface)
ASC:	Red-Orthic Tenosol
Location:	GDA94 Zone 50, 384514mE, 6612078mN
Map unit:	Dandaragan 3 subsystem (222Da_3)

Profile description

Depth (cm)	Description
0–10	Dusky-red (10R 3/3 moist) clayey sand; water repellent
50–70	Dark-red (10R 3/6 moist) clayey sand; red sand
100–200	Dark-red (10R 3/5 moist) sand; bright-red sand
200–300	Dusky-red (10R 3/4 moist) clayey sand; few ferromanganiferous soft segregations; dark-red sand
300–400	Dusky-red (10R 3/4 moist) sand; common ferromanganiferous soft segregations; dark-red sand; hard layer at 3.8m
400–500	Hard ironstone gravels to 4.2m, then glauconitic saprolite
500–600	Olive–yellow (5Y 6/6 moist); glauconitic clay, soft
600–700	Olive–yellow (5Y 6/6 moist); glauconitic clay, soft
700–800	Olive–yellow (5Y 6/6 moist); glauconitic clay, soft
800–900	Olive–yellow (5Y 6/6 moist); few sandstone glauconitic sandstone; glauconitic clay, soft
900–1000+	Olive–yellow (5Y 6/6 moist); few sandstone glauconitic sandstone; glauconitic clay, soft

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH ($CaCl_2$)	EC (mS/m)	OC_wb	B_$CaCl_2$	K_HCO_3	P_HCO_3	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	S	3	10	3	87	6.1	12	2.26	0.57	310	40	8.1[a]	5.95	0.65	1.05	0.42	5	0.03
50–70	S	2	3[a]			5.5	2	0.15	0.27	115	3	1.4[a]	0.81	0.23	0.23	0.10	7	0.04
100–200	S	5	3[a]			5.9	3											
200–300	S	25	15	3	82	5.8	4	0.26	0.41	58	6	2.9[a]	1.43	0.11	1.20	0.21	7	0.07
300–400	S	28	3[a]			6.3	2	0.14	0.32	81	12	2.6[a]	0.81	0.17	1.47	0.16	6	0.03
400–500		29				4.2	3											
500–600		5				4.1	6											
600–700		0				3.9	27	0.13	1.84	430	113	23.3[a]	3.24	0.98	14.86	4.21	18	1.45
700–800		0				4.1	42											
800–900		24				4.2	49											
900–1000		2				4.2	51	0.09	1.48	403	115	23.7[a]	4.07	0.92	14.01	4.66	20	1.21

a Values have been estimated or inferred from related observations or measurements.

Yellow deep sand

Representative site 1: P 0446

WA Soil Group: Yellow deep sand

Qualifier: GSV (Good sand, very deep)

ASC: Yellow-Orthic Tenosol

Location: GDA94 Zone 50, 392789mE, 6612576mN

Map unit: Rowes 1 typical phase (222Rw_1a)

Profile description

Depth (cm)	Description
0–10	Strong-brown (7.5YR 5/8 moist) sand; very weak consistence; single-grain structure; few charcoal
18–25	Reddish-yellow (7.5YR 6/8 moist) sand; very weak consistence; single-grain structure
36–43	Reddish-yellow (7.5YR 6/8 moist) sand; very weak consistence; single-grain structure
56–66	Reddish-yellow (7.5YR 6/8 moist) sand; very weak consistence; single-grain structure
76–86	Reddish-yellow (7.5YR 6/8 moist) sand; very weak consistence; single-grain structure; few ferruginous ironstone, same as substrate; 76–183cm is ferruginous; 76–86cm <10% of <6mm angular quartz
107–122	Reddish-yellow (7.5YR 6/8 moist) sand; very weak consistence; single-grain structure; common ferruginous ironstone, same as substrate

(continued)

Profile description continued

Depth (cm)	Description
137–152	Reddish-yellow (7.5YR 6/8 moist) sand; very weak consistence; single-grain structure; many angular ferruginous ironstone coarse gravel sized same as substrate
168–183	Reddish-yellow (7.5YR 6/8 moist) sand; olive–grey (5Y 5/2 moist) mottles; very weak consistence; single-grain structure; many ferruginous ironstone, same as substrate
198–221	Reddish-yellow (7.5YR 6/8 moist) sand; very few light olive–grey (5Y 6/2 moist) mottles; very weak consistence; single-grain structure
221–231	Reddish-yellow (7.5YR 6/8 moist) sand; very few light olive–grey (5Y 6/2 moist) mottles; very weak consistence; single-grain structure; few unidentified concretions
231–256	Red (10R 5/6 moist) sand; light-red (2.5YR 6/8 moist) mottles; very weak consistence; single-grain structure; few unidentified concretions
320–343+	Dark-red (10R 3/6 moist) coarse sand; very weak consistence; single-grain structure; very few unidentified concretions

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	EC (mS/m)	OC_wb	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP
0–10	S	4	6	2	92	6.0[a]	3	0.75	2.7[a]	1.80	0.09	0.60	0.16	6
18–25	S	1	7	2	91	5.8[a]	2							
36–43	S	2	10	1	89	5.8[a]	2							
56–66	S	4	8	2	90	5.9[a]	2							
76–86	S	10	9	2	89	6.1[a]	3							
107–122	S	15	10	2	88	6.3[a]	2							
137–152	S	36	10	2	88	6.5[a]	2							
168–183	S	68	8	5	87	6.4[a]	2							
198–221	S	34	8	4	88	6.0[a]	2							
221–231	S	28	9	4	87	5.7[a]	2							
231–256	S	29	10	3	87	5.7[a]	3							
320–343	KS	22	14	4	82	5.5[a]	3		0.6[a]	0.30	0.02	0.20	0.05	9

a Values have been estimated or inferred from related observations or measurements.

Brown deep sand

Representative site 1: WM0230

WA Soil Group:	Brown deep sand
Qualifier:	GSV (Good sand, very deep)
ASC:	Brown-Orthic Tenosol
Location:	GDA94 Zone 50, 373546mEn 6617249mN
Map unit:	Dandaragan 3 subsystem (222Da_3)

Profile description

Depth (cm)	Description
0–10	Very dark-brown (7.5YR 2.5/3 moist) sand; dry soil; water repellent
10–100	Dark reddish-brown (7.5YR 3/4 moist) medium fine sand; moist soil
100–200	Red (2.5YR 4/6 moist) medium fine sand; moist soil
200–300	Red (2.5YR 4/6 moist) medium fine sand; moist soil
300–400	Reddish-brown (2.5YR 4/4 moist) medium fine sand; moist soil
400–500	Reddish-brown (2.5YR 4/4 moist) medium fine sand; dry soil; few ferruginous gravels at 4.5m
500–600	Reddish-brown (2.5YR 4/4 moist) medium fine sand; dry soil
600–700	Red (2.5YR 4/6 moist) sand; dry soil
700–800	Red (2.5YR 5/6 moist) medium clay; dry soil
800–900	Red (2.5YR 5/6 moist) medium clay; dry soil
900–1000	Red (2.5YR 5/6 moist) medium clay; dry soil
1000–1100	Red (2.5YR 5/8 moist) medium clay; dry soil
1100–1200+	Red (2.5YR 4/6 moist) medium clay; dry soil

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	EC (mS/m)	OC_wb	B_CaCl$_2$	K_HCO$_3$	P_HCO$_3$	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	S	1	7	0	93	5.1	7	1.09	0.35	104	29	2.9[a]	2.16	0.24	0.39	0.11	4	0.07
10–100	MS	0	3[a]			4.8	1	0.24	0.18	19	8	0.3[a]	0.24	0.05	0.03	0.01	3	0.33
100–200	MS	0	3[a]			5.3	1											
200–300	MS	0	10	0	90	5.6	1	0.20	0.19	20	5	0.7[a]	0.48	0.04	0.13	0.03	4	0.06
300–400	MS	0	3[a]			5.9	1											
400–500	MS	12	3[a]			6.0	1	0.17	0.15	23	6	0.7[a]	0.46	0.02	0.18	0.04	6	0.10
500–600	MS	34	3[a]			5.7	2											
600–700	SCL	13	29	3	68	5.1	3	0.20	0.28	59	17	3.2[a]	0.92	0.10	2.14	0.07	2	0.07
700–800	MC	16	50[a]			5.4	5											
800–900	MC	4	50[a]			4.9	13											
900–1000	MC	14	50	5	45	5.0	7	0.22	0.96	205	265	7.5[a]	0.34	0.41	5.83	0.94	12	0.03
1000–1100	MC	19	50[a]			4.7	8											
1100–1200	MC	6	50[a]			4.8	13											

a Values have been estimated or inferred from related observations or measurements.

Yellow sandy earth

Representative site 1: DAN0132

WA Soil Group:	Yellow sandy earth
Qualifier:	NEU (Good neutral subsoil)
ASC:	Haplic, Mesotrophic, Yellow Kandosol
Location:	GDA94 Zone 50, 401345mE, 6625871mN
Map unit:	Capitella 2 yellow phase (222Cp_2a)

Profile description

Depth (cm)	Description
0–10	Dark greyish-brown (10YR 4/2 moist) very weak clayey fine sand; water repellent; pH 6.3 (soil paste); EC 3mS/m
10–40	Yellow (10YR 7/6 moist) very weak clayey fine sand; pH 5.9 (soil paste); EC 2mS/m
40–50+	Yellow (10YR 7/6 moist) sandy loam; pH 6.3 (soil paste); EC 1mS/m

Fair coloured sands LMU (21% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Yellow deep sand	75
Brown deep sand	20
Red deep sand	5

Yellow deep sand

Representative site 1: DAN0839

WA Soil Group: Yellow deep sand

Qualifier: FSV (Fair sand, very deep: fine sand throughout or sand increasing to clayey or loamy sand below 30cm and no hardpan, solid rock or clay layer present within the top 150cm)

ASC: Basic, Regolithic, Yellow-Orthic Tenosol

Location: GDA94 Zone 50, 364552mE, 6656391mN

Map unit: 222La_1

Profile description

Depth (cm)	Description
0–10	Brown (10YR 5/3 moist) sand with 3–5% clay; apedal, single-grain structure; many very fine roots; non-water-repellent; pH 5.9; EC 14mS/m; clear, smooth boundary
10–30	Brownish-yellow (10YR 6/6 moist) sand with 3–5% clay; very weak consistence; apedal, single-grain structure; many very fine roots; pH 5.6; EC 2mS/m; gradual, smooth boundary
30–120	Brownish-yellow (10YR 6/8 moist) loamy fine sand; very weak consistence; apedal, single-grain structure; few very fine roots; pH 6.5; clay content increases with depth; diffuse, smooth boundary
120–210	Brownish-yellow (10YR 6/8 moist) clayey fine sand; very weak consistence; apedal, single-grain structure; few very fine roots; pH 6.3; EC 1mS/m
210–350	Brownish-yellow (10YR 6/8 moist) sandy loam
350–390	Fine sandy loam
390–420+	Clayey coarse sand; 10% siliceous quartz fine-sized gravel and 5% ferruginous ironstone medium-sized gravel; pH 6.4

Chemical analysis

Depth (cm)	Texture	CF%	clay	silt	sand	pH	Al_$CaCl_2$	EC	OC_wb	K_HCO_3	P_HCO_3	P_kjel	PRI	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	WCS	1	2	1	97	5.4	1	6	0.61	38	9	82	1	1.7[a]	1.28	0.06	0.27	0.06	4	0.02
10–30	WCS	0	4	1	95	4.8	1	1	0.17	17	1	27	3	0.6[a]	0.44	0.03	0.11	0.04	6	0.03
30–60	LFS	0	6	1	93	5.5	1	1	0.19	17	1	23	6	0.6[a]	0.41	0.03	0.14	0.05	8	0.01
60–90	LFS	0	5[a]			5.9[b]														
90–120	LFS	1	5[a]			5.9[b]														
120–150	CFS	1	6	2	92	6.1		2	0.05	18	1	18	15	0.6[a]	0.27	0.03	0.20	0.06	11	0.01
150–180	CFS	0	8[a]			5.7[b]		1												
180–210	CFS	0	6	2	92	6.2		1	0.04	14	1	20	13	0.6[a]	0.29	0.02	0.20	0.06	11	0.01

a Values have been estimated or inferred from related observations or measurements.

b Field pH measurement which has been converted from 'in water' to 'in $CaCl_2$' (calcium chloride).

Brown deep sand

Representative site 1: DAN0856

WA Soil Group:	Brown deep sand
Qualifier:	FSV (Fair sand, very deep)
ASC:	Basic, Arenic, Brown-Orthic Tenosol
Location:	GDA94 Zone 50, 381176mE, 6607710mN
Map unit:	Dandaragan 2 yellow phase (222Da_2a)

Profile description

Depth (cm)	Description
0–15	Brown (10YR 4/3 moist) sand with 3–5% clay; very weak consistence; apedal, single-grain structure; many very fine roots; rapid permeability, non-water-repellent; pH 5.1; EC 7mS/m; clear, smooth boundary
15–50	Yellowish-brown (10YR 5/6 moist) sand with 3–5% clay; very weak consistence; apedal, single-grain structure; few very fine roots; rapid permeability; pH 5.1; EC 2mS/m; gradual, smooth boundary
50–150	Brownish-yellow (10YR 6/8 moist) loamy fine sand; very weak consistence; apedal, single-grain structure; few very fine roots; rapid permeability; pH 5.5; EC 1mS/m; pH increases from 5.5 to 5.9 with depth
150–200+	Yellow (2.5Y 7/8 moist) clayey fine sand; very weak consistence; apedal, single-grain structure; few very fine roots; rapid permeability; pH 6; EC 1mS/m
400–420+	Yellow (2.5Y 7/8 moist) fine sandy loam; apedal, single-grain structure; pH 6.1; EC 1mS/m

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	Al_CaCl$_2$	EC (mS/m)	OC_wb	K_HCO$_3$	P_HCO$_3$	P_kjel	PRI	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–15	WCS	0	3	1	96	4.5	2	6	0.75	50	20	127	1	1.9[a]	1.57	0.07	0.16	0.11	6	0.21
15–50	WCS	0	3	1	96	4.5	1	1	0.17	16	4	57	2	0.5[a]	0.41	0.02	0.05	0.04	8	0.14
50–100	LFS	0	4	0	96	5.1	1	1	0.08	12	1	40	3	0.5[a]	0.38	0.01	0.05	0.02	4	0.01
100–150	LFS	0	5[a]			4.9[b]		1												
150–200	CFS	0	4	1	95	5.9		1	0.05	10	1	30	6	0.4[a]	0.23	0.01	0.11	0.05	13	0.01
400–420	FSL	0	4	1	95	6.0		6	0.04	11	1	21	12	0.4[a]	0.15	0.01	0.18	0.03	8	0.01

a Values have been estimated or inferred from related observations or measurements.

b Field pH measurement which has been converted from 'in water' to 'in $CaCl_2$' (calcium chloride).

Red deep sand

Representative site 1: REF MRA09

WA Soil Group: Red deep sand

Qualifier: FSV (Fair sand, very deep)

ASC: Basic, Regolithic, Red-Orthic Tenosol

Location: GDA94 Zone 50, 385862mE, 6604399mN

Map unit: Dandaragan 3 subsystem (222Da_3)

Profile description

Depth (cm)	Description
0–6	Dark-red (2.5YR 3/5 moist) loamy sand; very weak dry consistence; smooth-ped fabric; 2% fine-sized quartz gravel; clear boundary
6–15	Dark-red (2.5YR 3/6 moist) loamy sand; very weak dry consistence; smooth-ped fabric; 3% fine-sized quartz gravel; gradual boundary
15–35	Red (2.5YR 4/6 moist) loamy sand; very weak dry consistence; smooth-ped fabric; 2% fine-sized quartz gravel; diffuse boundary
35–60	Red (2.5YR 4/7 moist) loamy sand; very weak dry consistence; smooth-ped fabric; 2% fine-sized quartz gravel and ferruginous ironstone gravel; gradual boundary
60–100	Red (2.5YR 4/8 moist) loamy sand; very weak dry consistence; smooth-ped fabric; 4% fine-sized quartz gravel and ferruginous ironstone gravel

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	EC	OC_wb	K_HCO_3	P_HCO_3	P_kjel	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP
0–6	LS	2[a]	6	2	92	5.2	2	0.89	36	2	120	4.0	1.80	0.10	0.50	0.05	2
6–15	LS	3[a]	6	3	91	5.6	2	0.57	32	1	100	4.0	2.20	0.05	0.70	0.05	2
15–35	LS	2[a]	7	2	91	6.1	1	0.22	46	1	110	3.0	1.70	0.10	0.50	0.05	2
35–60	LS	2[a]	7	3	90	6.3	2	0.22	50	1	100	2.0	1.40	0.10	0.60	0.05	3
60–100	LS	4[a]	7	2	91	6.5	2	0.22	41	1	92	2.0	1.20	0.10	0.70	0.05	3

a Values have been estimated or inferred from related observations or measurements.

Red deep sand

Representative site 2: WM0227

WA Soil Group:	Red deep sand
Qualifier:	FSV (Fair sand, very deep)
ASC:	Basic, Regolithic, Red-Orthic Tenosol
Location:	GDA94 Zone: 50, 372592mE, 6612567mN
Map unit:	Dandaragan 3 subsystem (222Da_3)

Profile description

Depth (cm)	Description
0–10	Brown (7.5YR 5/4 moist) coarse sand
10–50	Reddish-yellow (7.5YR 7/8 moist) medium sand
100–200	Reddish-yellow (7.5YR 7/8 moist) medium sand
200–300	Reddish-yellow (7.5YR 7/8 moist) medium sand
300–400	Reddish-yellow (7.5YR 7/8 moist) medium sand
400–500	Reddish-yellow (7.5YR 7/8 moist) medium sand
500–600	Reddish-yellow (7.5YR 6/8 moist) medium sand; few ferruginous gravels
600–700	Reddish-yellow (7.5YR 6/8 moist) coarse sand; very few ferruginous gravels
700–800	Strong-brown (7.5YR 5/8 moist) coarse sand
800–900	Strong-brown (7.5YR 5/8 moist) coarse sand
900–1000	Reddish-yellow (7.5YR 6/8 moist) coarse sand
1000–1100+	Reddish-yellow (7.5YR 6/8 moist) coarse sand

Chemical analysis

Depth (cm)	Texture	CF%	clay	silt	sand	pH	EC	OC_wb	B_CaCl_2	K_HCO_3	P_HCO_3	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	KS	2	6	0	94	6.8	6	0.90	0.22	84	29	3.3[a]	2.78	0.12	0.36	0.05	2	0.04
10–50	MS	0	3[a]			4.9	2	0.13	0.22	16	2	0.4[a]	0.24	0.03	0.07	0.02	6	0.17
100–200	MS	0	3[a]			6.0	1											
200–300	MS	0	9	1	90	6.2	1	0.08	0.19	15	1	0.5[a]	0.35	0.02	0.13	0.03	6	0.12
300–400	MS	0	3[a]			6.3	1											
400–500	MS	0	3[a]			7.1	2	0.19	0.19	23	1	0.5[a]	0.24	0.05	0.16	0.02	4	0.05
500–600	MS	13	3[a]			6.0	1											
600–700	KS	8	7	2	91	6.1	1	0.05	0.12	8	1	0.2[a]	0.10	0.01	0.08	0.02	10	0.07
700–800	KS	5	3[a]			5.9	1											
800–900	KS	4	3[a]			6.4	1											
900–1000	KS	2	5	1	94	6.3	1	0.03	0.10	8	1	0.1[a]	0.05	0.01	0.04	0.02	17	0.03
1000–1100	KS	2	3[a]			6.3	1											

a Values have been estimated or inferred from related observations or measurements.

Poor coloured sands LMU (15% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Yellow deep sand	97
Brown deep sand	3

Yellow deep sand

Representative site 1: REF MRA06

WA Soil Group:	Yellow deep sand
Qualifier:	PSV (Poor sand, very deep: sand is mainly coarse or medium grained and no hardpan, solid rock or clay layer present within the top 150 cm)
ASC:	Basic, Arenic, Yellow-Orthic Tenosol
Location:	GDA94 Zone 50, 397964mE, 6645431mN
Map unit:	Agaton 5 low dunes phase (222Ag_5a)

Profile description

Depth (cm)	Description
A1, 0–8	Dark yellowish-brown (10YR 4/5 moist) sand; loose consistence; apedal, single-grain structure; clear boundary
B1, 8–30	Brownish-yellow (10YR 6/6 moist) sand; loose consistence; apedal, single-grain structure; gradual boundary
B21, 30–60	Brownish-yellow (10YR 6/8 moist) sand; loose consistence; apedal, single-grain structure; diffuse boundary
B22, 60–110	Brownish-yellow (10YR 6/8 moist) sand; loose consistence; apedal, single-grain structure

Chemical analysis

Depth (cm)	Texture	Clay	Silt	Sand	pH	EC (mS/m)	OC_wb	K_HCO$_3$	P_HCO$_3$	P_kjel	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP
0–8	S	1	1	98	5.0	1	0.24	12	1	10	0.5	0.40	0.05	0.05	0.05	10
8–30	S	2	1	97	5.1	1	0.12	5	1	9	0.5	0.30	0.05	0.05	0.05	11
30–60	S	1	1	98	5.4	1	0.09	5	1	8	0.5	0.20	0.05	0.05	0.05	12
60–110	S	2	1	97	5.6	1	0.06	5	1	8	0.5	0.20	0.05	0.10	0.05	12

Brown deep sand

Representative site 1: REF MRA05

WA Soil Group:	Brown deep sand
Qualifier:	SAC (Acid sand: sand is strongly acid (pH_w <5.6) within the top 30cm)
ASC:	Basic Arenic Bleached-Orthic Tenosol
Location:	GDA94 Zone 50, 400896mE, 6645445mN
Map unit:	Agaton 5 low dunes phase (222Ag_5a)

Profile description

Depth (cm)	Description
0–10	Dark greyish brown (10YR 4/2 moist) sand; loose consistence; apedal, single-grain structure; 2% siliceous quartz fine-sized gravel; clear boundary
10–20	Brown (10YR 5/3 moist) sand; loose consistence; apedal, single-grain structure; 1% siliceous quartz fine-sized gravel; gradual boundary
20–35	Pale-brown (10YR 6/3 moist) sand; loose consistence; apedal, single-grain structure; clear boundary
35–60	Yellow (10YR 7/6 moist) sand; loose consistence; apedal, single-grain structure; gradual boundary
60–110	Yellow (10YR 7/8 moist) sand; loose consistence; apedal, single-grain structure

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	EC (mS/m)	OC_wb	K_HCO_3	P_HCO_3	P_kjel	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP
0–10	S	2[a]	1	1	98	4.5	2	0.41	15	1	9	0.5	0.40	0.05	0.20	0.05	9
10–20	S	1[a]	1	1	98	4.6	2	0.24	5	1	9	0.5	0.20	0.05	0.05	0.05	12
20–35	S		1	1	98	4.9	1	0.13	5	1	8	0.5	0.05	0.05	0.05	0.05	18
35–60	S		1	1	98	5.7	1	0.05	5	1	9	0.5	0.05	0.05	0.05	0.05	18
60–110	S		1	1	98	5.6	1	0.05	5	1	9	0.5	0.05	0.05	0.05	0.05	18

a Values have been estimated or inferred from related observations or measurements.

Poor pale sands LMU (12% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Pale deep sand	52
Gravelly pale deep sand	48

Pale deep sand

Representative site 1: SC2 BAL2

WA Soil Group:	Pale deep sand
Qualifier:	SAC (Acid sand)
ASC:	Acidic, Arenic, Bleached-Orthic Tenosol
Location:	GDA94 Zone 50, 355856mE, 6641040mN
Map unit:	224Ye_3a

Profile description

Depth (cm)	Description
0–20	Greyish-brown (10YR 5/2 moist), grey (10YR 6/1 dry) medium sand; loose, dry consistence; apedal, single-grain structure; sandy fabric; many very fine (<1mm) grass roots; rapid permeability; fine to medium sand; clear, smooth boundary
20–50	Light brownish-grey (10YR 6/2 moist), light-grey (10YR 7/2 dry) medium sand; loose, dry consistence; apedal, single-grain structure; sandy fabric; few very fine grass roots; rapid permeability; fine to medium sand; diffuse, smooth boundary
50–110	Yellow (10YR 8/6 moist), very pale-brown (10YR 8/3 dry) medium sand; mottles; loose, dry consistence; apedal, single-grain structure; sandy fabric; rapid permeability; roots 1/100cm^2; gradual, smooth boundary
110–150	Yellow (10YR 8/6 moist), very pale-brown (10YR 8/4 dry) medium sand with 3–5% clay; moderately moist soil; apedal, massive structure; earthy fabric; 5% subrounded ferruginous ironstone gravel fine sized; soft irregular nodules and subrounded ferruginous ironstone gravel medium sized; moderately rapid permeability; Friable, Old decayed carbonic root channels 5mm
150–170+	Yellow (10YR 7/8 moist), very pale-brown (10YR 8/4 dry) clayey medium sand; very few mottles; moist soil; apedal, massive structure; earthy fabric; 5% subrounded ferruginous ironstone fine-sized gravel; variegated red and subrounded ferruginous ironstone medium-sized gravel; moderately rapid permeability; friable

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	EC	OC_wb	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	MS	0[a]	1	1	98	5.2	4	0.77	1.9[a]	1.59	0.03	0.21	0.04	2	0.03
10–20	MS	0[a]	1	1	98	4.7	1	0.26	0.5[a]	0.42	0.01	0.06	0.01	2	0.06
20–30	MS	0[a]	1	1	98	4.7	1	0.17	0.2[a]	0.18	0.01	0.04	0.01	4	0.05
30–50	MS	0[a]	1	1	98	4.6	1	0.13	0.2[a]	0.13	0.01	0.03	0.01	6	0.07
50–80	MS	0[a]	2	1	97	4.6	1	0.09	0.1[a]	0.06	0.01	0.02	0.01	10	0.09
80–110	MS	0[a]	3	1	96	5.0	1	0.08	0.2[a]	0.12	0.01	0.03	0.01	6	0.04
110–150	WCMS	5[a]	3	1	96	5.4	1	0.06	0.2[a]	0.12	0.01	0.03	0.01	6	0.01
150–170	CMS	5[a]	14	1	85	5.6	1	0.10	0.7[a]	0.39	0.02	0.22	0.02	3	0.01

a Values have been estimated or inferred from related observations or measurements.

Gravelly pale deep sand

Representative site 1: P 0460

WA Soil Group:	Gravelly pale deep sand
Qualifier:	PSV (Poor sand, very deep)
ASC:	Sesqui-Nodular Tenosol
Location:	GDA94 Zone 50, 373977mE, 6619855mN
Map unit:	Dandaragan 3 subsystem (222Da_3)

Profile description

Depth (cm)	Description
0–10	Grey (2.5Y 5/1 moist) weak clayey sand; apedal, single-grain structure; gradual boundary
10–45	White (2.5Y 8/2 moist) very weak clayey sand; apedal, single-grain structure; clear boundary
45–50+	Pale-yellow (2.5Y 8/3 moist) gravel; apedal, 70% subrounded fine- to coarse-sized ironstone gravel

Good gravels LMU (10% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Deep sandy gravel	44
Duplex sandy gravel	43
Loamy gravel	14

Duplex sandy gravel

Representative site 1: REF MRA07

WA Soil Group:	Duplex sandy gravel
Qualifier:	CNE (Neutral subsoil: clay loam to clay subsoil above 80cm is neutral (pH_w 6.0-8.0))
ASC:	Ferric, Dystrophic, Brown Chromosol
Location:	GDA94 Zone 50, 348307mE, 6636584mN
Map unit:	224Ye_2

Profile description

Depth (cm)	Description
0–7	Dark-grey (10YR 4/1 moist) loamy sand; very weak, dry consistence; smooth-ped fabric; 5% gravel sized; clear boundary
7–20	Yellowish-brown (10YR 5/4 moist) loamy sand; loose consistence; apedal, single-grain structure; 60% ferruginous gravel; sharp boundary
20–50	Dark yellowish-brown (10YR 3/6 moist) medium clay; few reddish-brown (2.5YR 5/4 moist) mottles; firm, moist consistence; apedal, massive structure; 8% gravel; gradual boundary
50–70	Strong-brown (7.5YR 5/8 moist) medium clay; red (2.5YR 4/6 moist) mottles; firm, moist consistence; pedal, moderate structure; porous; gradual boundary
70–100	Brownish-yellow (10YR 6/6 moist) sandy clay; white (10YR 8/2 moist) mottles; firm, moist consistence; apedal, massive structure; porous

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	EC (mS/m)	OC_wb	K_HCO_3	P_HCO_3	P_kjel	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP
0–7	LS	5[a]	4	2	94	4.7	2	0.83	20	1	36	2.0	0.90	0.05	0.20	0.05	4
7–20	LS	60[a]	7	2	91	4.8	2	0.83	20	1	43	2.0	0.90	0.10	0.40	0.05	3
20–50	MC	8[a]	40	4	56	5.1	3	0.50	51	1	30	3.0	1.00	0.20	0.90	0.05	2
50–70	MC		47	7	46	5.1	2	0.13	53	2	25	2.0	0.80	0.10	1.00	0.05	3
70–100	SC		39	5	56	5.1	2	0.09	47	1	21	2.0	0.70	0.10	0.90	0.05	3

a Values have been estimated or inferred from related observations or measurements.

Duplex sandy gravel

Representative site 2: DAN0845

WA Soil Group:	Duplex sandy gravel
Qualifier:	CNE (Neutral subsoil)
ASC:	Ferric Mesotrophic Yellow Chromosol
Location:	GDA94 Zone 50, 363800mE, 6646671mN
Map unit:	Boothendarra 4 subsystem (224Bh_4)

Profile description

Depth (cm)	Description
0–5	Black (7.5YR 2/1 moist) humic loamy fine sand; apedal, single-grain structure; 1% ferruginous ironstone gravel; strongly water repellent; pH 6.9; EC 19mS/m; clear, smooth boundary
5–10	Dark-brown (7.5YR 3/3 moist) loamy fine sand; apedal, single-grain structure; 5% rounded ferruginous ironstone gravel fine sized; strongly water repellent; pH 5.5; EC 14mS/m; clear, smooth boundary
10–40	Pink (7.5YR 7/4 moist) sandy gravel texture; apedal, single-grain structure; 45% rounded ferruginous ironstone gravel fine sized and 20% rounded ferruginous ironstone gravel medium sized; pH 5.6; EC 4mS/m; clayey fine sandy gravel; clear, smooth boundary
40–100+	Brownish-yellow (10YR 6/8 moist) fine sandy clay loam; few medium distinct white (10YR 8/2 moist) mottles and very few fine distinct red (2.5YR 5/6 moist) mottles; very firm consistence, slightly sticky; apedal, massive structure; 9% rounded ferruginous ironstone gravel fine sized and 1% rounded ferruginous ironstone gravel medium sized; pH 6.2; EC 9mS/m; mottle abundance increases with depth

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	Al_$CaCl_2$	EC (mS/m)	OC_wb	K_HCO_3	P_HCO_3	P_kjel	PRI	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–5	LFS	7	3	3	94	5.4	1	22	4.28	377	61	424	3	9.9[a]	7.04	0.91	1.62	0.37	4	0.02
5–10	LFS	9	4	4	93	4.7	1	15	1.32	204	34	196	5	2.5[a]	1.51	0.42	0.34	0.24	10	0.09
10–40	GR	45	4	5	90	4.6	1	2	0.12	49	3	82	3	0.6[a]	0.26	0.09	0.17	0.09	15	0.07
40–70	FSCL	19	35	5	60	5.8		7	0.05	76	1	50	2000	4.9[a]	1.52	0.12	2.82	0.43	9	0.01
70–110	FSCL	9	36	5	59	5.9		7	0.03	63	1	46	2000	4.6[a]	1.22	0.11	2.82	0.44	10	0.02

a Values have been estimated or inferred from related observations or measurements.

Loamy gravel

Representative site 1: CHT0652

WA Soil Group:	Loamy gravel
Qualifier:	CNE (Neutral subsoil)
ASC:	Ferric, Mesotrophic, Red Kandosol
Location:	GDA94 Zone 50, 397365mE, 6527651mN
Map unit:	222DaMD1

Profile description

Depth (cm)	Description
0–12	Reddish-brown (5YR 4/3 moist) sandy loam; moist soil; apedal; earthy fabric; 20% subrounded ferruginous ironstone gravel coarse-sized; pH 7.3 (1:5 water); EC 5mS/m
12–30	Yellowish-red (5YR 5/8 moist) sandy clay loam; moist soil; apedal; earthy fabric; 60% subrounded ferruginous ironstone gravel coarse-sized; pH 7.2 (1:5 water); EC 1mS/m
30–55	Reddish-brown (5YR 5/4 moist) sandy loam; moist soil; apedal; earthy fabric; 80% subrounded ferruginous ironstone gravel coarse-sized; pH 8 (1:5 water); EC 1mS/m
55–80+	Red (2.5YR 4/8 moist) medium clay; abundant fine distinct brown (7.5YR 4/2 moist) mottles and common fine distinct strong-brown (7.5YR 5/8 moist) mottles; moderately moist soil; pedal; pH 7.8 (1:5 water); EC 1mS/m

Shallow soils LMU (4% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Shallow gravel	70
Red shallow sand	15
Pale shallow sand	9
Yellow/brown shallow sand	<1

Shallow gravel

Representative site 1: STU0163

WA Soil Group:	Shallow gravel
Qualifier:	SAM (Sandy matrix: stones or gravels are surrounded by a coarse to clayey sand sandy matrix)
ASC:	Petroferric, Sesqui-Nodular Tenosol
Location:	GDA94 Zone 50, 389709mE, 6625041mN
Map unit:	Rowes 2 subsystem (222Rw_2)

Profile description

Depth (cm)	Description
0–10	Very dark greyish-brown (10YR 3/2 moist) loamy sand; dry soil; apedal; 30% subrounded ferruginous ironstone medium-sized gravel and 10% subrounded tabular ferruginous ironstone coarse-sized gravel; water repellent; pH 6.5 (soil paste); clear boundary
10–30	Dark greyish-brown (10YR 4/2 moist) clayey sand; dry soil; apedal; 30% subrounded ferruginous ironstone medium-sized gravel and 30% subrounded tabular ferruginous ironstone coarse-sized gravel; water repellent; pH 6 (soil paste); gradual boundary
30–40	Yellowish-brown (10YR 5/8 moist) sandy loam; dry soil; apedal; 40% subrounded ferruginous ironstone medium-sized gravel and 10% subrounded tabular ferruginous ironstone coarse-sized gravel; pH 6 (soil paste)
40+	Strongly cemented, massive, ferricrete pan

Red shallow sand

Representative site 1: DAN101

WA Soil Group:	Red shallow sand
Qualifier:	GSR (Good sand, rock substrate: sand is mainly fine-grained, loamy or clayey and a hardpan, cemented layer or solid rock is present at 30-80cm)
ASC:	Ferric-Petroferric, Red-Orthic Tenosol
Location:	MGA94 Zone 50, 380639mE, 6605393mN
Map unit:	Dandaragan 3 subsystem (222Da_3)

Profile description

Depth (cm)	Description
0–10	Dusky-red (10R 3/3 moist), weak, clayey fine sand; apedal, single-grain; pH 6.9 (soil paste); EC 6mS/m
10–50	Weak-red (10R 4/4 moist), weak, clayey fine sand; apedal, single-grain; pH 6.3 (soil paste); EC 3mS/m
50–60+	Red (10R 4/6 moist), weak, clayey fine sand; apedal, single-grain; pH 6.1 (soil paste); EC 3mS/m; Notes: ferruginous sandstone gravel - mixture of haematite colour and goethite colour

Pale shallow sand

Representative site 1: DAN0367

WA Soil Group:	Gravelly pale deep sand
Qualifier:	GSR (Good sand, rock substrate)
ASC:	Petroferric, Bleached-Leptic Tenosol
Location:	GDA94 Zone 50, 395639mE, 6632403mN
Map unit:	Capitella 1 sandy gravel phase (222Cp_1a)

Profile description

Depth (cm)	Description
0–10	Light brownish-grey (2.5Y 6/3 moist) loamy sand
10–50	Pale-yellow (2.5Y 8/3 moist), very weak, clayey fine sand
50–51+	Strongly cemented, massive, ferricrete pan

Fair pale sands LMU (4% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Pale deep sand	76
Pale sandy earth	22
Gravelly pale deep sand	2

Pale deep sand

Representative site 1: DAN0841

WA Soil Group:	Pale deep sand
Qualifier:	GSV (Good sand, very deep)
ASC:	Basic, Ferric, Bleached-Orthic Tenosol
Location:	GDA94 Zone 50, 367562mE, 6656395mN
Map unit:	Coalara 5 plain phase (222Co_5a)

Profile description

Depth (cm)	Description
0–10	Light brownish-grey (2.5Y 6/2 moist) humic fine sand with 3–5% clay; apedal, single-grain structure; common very fine roots; strongly water repellent; pH 6.5; EC 5mS/m; clear, smooth boundary
10–40	Pale-yellow (2.5Y 7/3 moist) fine sand with 1–3% clay; apedal, single-grain structure; few fine roots; pH 5.9; EC 1mS/m; gradual, smooth boundary
40–70	Yellow (2.5Y 7/6 moist) loamy fine sand; apedal, single-grain structure; few very fine roots; pH 6.2; EC 1mS/m
70–100	Yellow (10YR 7/6 moist) clayey fine sand; very few light-grey (10YR 7/2 moist) mottles; apedal, single-grain structure; few very fine roots; pH 6.2; EC 1mS/m
100–130	Yellow (10YR 7/8 moist) clayey fine sand; very few light-grey (10YR 7/2 moist) mottles; apedal, single-grain structure; few very fine roots; 5% subangular siliceous quartz gravel fine sized and 2% subrounded ferruginous ironstone gravel medium sized; pH 6.2; EC 1mS/m
130–160	Brownish-yellow (10YR 6/8 moist) clayey fine sand; very few light grey (10YR 7/2 moist) mottles; apedal, single-grain structure; few very fine roots; 5% subangular siliceous quartz gravel fine-sized and 2% ferruginous ironstone gravel; pH 6.2; EC 1mS/m
160–190	Brownish-yellow (10YR 6/8 moist) clayey fine sand; very few light grey (10YR 7/2 moist) mottles; apedal, single-grain structure; few very fine roots; 5% subangular siliceous quartz gravel fine-sized and 10% subrounded ferruginous ironstone gravel medium-sized; pH 6.4; clear, wavy boundary
190–220	Yellow (2.5Y 7/6 moist) sandy gravel texture; 5% subangular siliceous quartz gravel fine sized and 50% subrounded ferruginous ironstone gravel medium-sized and 15% subrounded ferruginous ironstone gravel coarse-sized; pH 6.4; gradual, irregular boundary
220–280	Yellow (2.5Y 7/6 moist) sandy gravel texture; common very coarse distinct red (2.5YR 4/8 moist) redox mottles and common very coarse distinct yellow (10YR 8/6 moist) redox mottles; 5% subangular siliceous quartz gravel fine-sized and 30% subrounded ferruginous ironstone gravel medium sized and 35% subrounded ferruginous ironstone gravel coarse-sized; pH 6.4; clear, irregular boundary
280–300+	Yellow (2.5Y 7/6 moist) gravel texture; many very coarse distinct red (2.5YR 4/8 moist) redox mottles; 30% subangular siliceous quartz gravel fine-sized and 10% subrounded ferruginous ironstone gravel medium-sized; pH 6.2; EC 0mS/m

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	Al_$CaCl_2$	EC (mS/m)	OC_wb	K_HCO_3	P_HCO_3	P_kjel	PRI	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	WCFS	1	1	2	98	5.0	1	4	0.57	22	2	45	0	1.2[a]	0.90	0.04	0.12	0.11	9	0.02
10–40	VWCFS	1	0	1	99	5.0	1	1	0.09	5	2	27	1	0.3[a]	0.19	0.02	0.02	0.11	32	0.02
40–70	LFS	2	0	1	98	5.3	1	1	0.05	5	1	28	1	0.3[a]	0.14	0.01	0.01	0.10	38	0.01
70–100	CFS	5	2	1	97	5.4	1	1	0.06	5	1	28	3	0.3[a]	0.19	0.01	0.02	0.06	21	0.01
100–130	CFS	5[a]	8			5.6[b]		1												
130–160	CFS	7[a]	8			5.6[b]		1												
160–190	CFS	21	3	1	96	5.6		1	0.05	5	1	30	5	0.3[a]	0.14	0.01	0.09	0.04	14	0.01
190–220	GR	72				5.8[b]														
220–250	GR	62	11	1	88	5.9		2	0.06	14	1	28	24	1.1[a]	0.53	0.01	0.48	0.08	7	0.01
250–280	GR	37				5.8[b]														
280–300	GR	22	11	2	87	5.7		1	0.04	5	1	22	15	0.8[a]	0.31	0.01	0.37	0.07	9	0.01

a Values have been estimated or inferred from related observations or measurements.

b Field pH measurement which has been converted from 'in water' to 'in $CaCl_2$' (calcium chloride).

Pale sandy earth

Representative site 1: DAN0399

WA Soil Group:	Pale sand earth
Qualifier:	NEU (Good neutral subsoil)
ASC:	Grey Kandosol
Location:	GDA94 Zone 50, 388575mE, 6622496mN
Map unit:	Rowes 2 subsystem (222Rw_2)

Profile description

Depth (cm)	Description
0–10	Dark-brown (7.5YR 3/2 moist), humic, loamy fine sand; apedal, single-grain; pH 6.6 (soil paste); EC 10mS/m; gradual boundary
10–30	Dark greyish-brown (7.5YR 5/2 moist), fine sandy loam; apedal, single-grain; pH 6.5 (soil paste); EC 20mS/m; 40% fine-to coarse-sized ironstone gravel; clear boundary
30–45	Yellowish-red (5YR 5/6 moist), fine sandy clay loam; apedal, pH 6.2 (soil paste); EC 110mS/m; 10% fine- to coarse-sized ironstone gravel; gradual boundary
45–50+	Red (2.5YR 4/6 moist), fine sandy clay loam; apedal, 10% fine- to coarse-sized ironstone gravel

Poor gravels LMU (2% of focus area)

WA Soil Group in LMU	Percentage in LMU (%)
Deep sandy gravel	100

Deep sandy gravel

Representative site 1: DAN0844

WA Soil Group:	Deep sandy gravel
Qualifier:	PSV (Poor sand, very deep)
ASC:	Basic, Regolithic, Sesqui-Nodular Tenosol
Location:	GDA94 Zone 50, 367604Me, 6656514mN
Map unit:	Coalara 5 plain phase (222Co_5a)

Profile description

Depth (cm)	Description
0–10	Dark-grey (10YR 4/1 moist), greyish-brown (10YR 5/2 dry), loamy fine sand; common, very fine roots; 10% subrounded ferruginous ironstone gravel medium-sized and 10% subrounded ferruginous ironstone gravel coarse-sized; pH 5.6; EC 24mS/m; abrupt, smooth boundary
10–50	Pale-brown (10YR 6/3 moist), light grey (10YR 7/2 dry) sandy gravel texture; few very fine roots; 25% subrounded ferruginous ironstone gravel medium-sized and 50% subrounded ferruginous ironstone gravel coarse-sized; pH 5.8; EC 2mS/m; weakly clayey fine sandy gravel
50–80	Very pale-brown (10YR 7/4 moist), white (10YR 8/2 dry) sandy gravel texture; few very fine roots; 10% subangular siliceous quartz fine gravel sized and 60% subrounded ferruginous ironstone gravel medium-sized and 10% subrounded ferruginous ironstone gravel coarse-sized; pH 6.4; EC 3mS/m; weakly clayey medium to fine sandy gravel
80–140	Very pale-brown (10YR 7/4 moist), very pale-brown (10YR 8/3 dry) sandy gravel texture; few very fine roots; 10% subangular siliceous quartz gravel fine-sized and 20% subrounded ferruginous ironstone gravel medium-sized and 50% subrounded ferruginous ironstone gravel coarse-sized; pH 6.4; EC 1mS/m; weakly clayey coarse to fine sandy gravel; gradual, irregular boundary
140–170	Brownish-yellow (10YR 6/6 moist), gravelly coarse sand with 3–5% clay; 15% subrounded siliceous quartz gravel fine-sized and 35% subrounded ferruginous ironstone gravel medium-sized; pH 6.6; EC 2mS/m; gradual, irregular boundary
170–200+	Apedal, massive structure

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	Al_CaCl2	EC	OC_wb	K_HCO3	P_HCO3	P_kjel	PRI	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	LFS	40	2	2	96	5.2	1	11	2.30	128	12	179	–1	5.2[a]	4.08	0.23	0.72	0.18	3	0.02
10–50	GR	81	2	2	96	4.8	1	1	0.26	13	3	54	1	0.5[a]	0.40	0.02	0.06	0.06	11	0.05
50–80	GR	83	2	2	97	5.2	1	1	0.12	17	2	47	2	0.5[a]	0.34	0.03	0.08	0.08	15	0.01
80–110	GR	84				5.8[b]		1												
110–140	GR	83	5	2	93	5.7		2	0.16	53	1	56	8	2.0	0.73	0.11	0.40	0.06	4	
140–170	WCKS	67	13	3	85	5.8		2	0.13	53	1	65	15	2.0	0.96	0.10	0.65	0.11	6	
170–200		50	23	3	74	5.9		2	0.06	38	1	68	80	1.4[a]	0.58	0.05	0.71	0.10	7	0.01

a Values have been estimated or inferred from related observations or measurements.

b Field pH measurement which has been converted from 'in water' to 'in $CaCl_2$' (calcium chloride).

Good loams LMU (2% of focus area)

WA Soil Group in LMU	Percentage of LMU (%)
Red loamy earth	58
Brown loamy earth	34
Red deep loamy duplex	6

Red loamy earth

Representative site 1: DAN0894

WA Soil Group:	Red loamy earth
Qualifier:	NEU (Good neutral subsoil)
ASC:	Mesotrophic Red Kandosol
Location:	GDA94 Zone 50, 382348Me, 6603129mN
Map unit:	Dandaragan 4 slopes phase (222Da_4a)

Profile description

Depth (cm)	Description
0–5	Very dark-grey (5YR 3/1 moist), fine sandy loam; pH 6.2 (soil paste); EC 79mS/m
5–30	Very dark-grey (5YR 3/1 moist) sandy loam; strong consistence; pH 5.8 (soil paste); EC 83mS/m; Notes: Some fine, weak iron gravel at bottom of layer
30–50+	Dark reddish-brown (5YR 3/2 moist) sandy light clay; no slaking; partial dispersion; pH 6.1 (soil paste); EC 8mS/m

Brown loamy earth

Representative site 1: DAN0852

WA Soil Group:	Brown loamy earth
Qualifier:	NEU (Good neutral subsoil)
ASC:	Melanic, Mesotrophic, Black Chromosol
Location:	GDA94 Zone 50, 379001Me, 6606548mN
Map unit:	Dandaragan 4 slopes phase (222Da_4a)

Profile description

Depth (cm)	Description
0–10	Dark reddish-brown (5YR 3/2 moist) loam; few, fine, faint yellowish-red (5YR 5/8 moist) redox mottles; moist soil; pedal, weak, 50–100mm, platy structure; rough-ped fabric; moderate permeability; pH 6.1; EC 4mS/m; clear, wavy boundary
10–30	Dark reddish-brown (5YR 3/2 moist) sandy clay loam; firm moist consistence; apedal, massive structure; 5% subrounded ferruginous ironstone gravel fine-sized; moderately slow permeability, non-dispersing; pH 6.4; EC 2mS/m; gradual, smooth boundary
30–50	Dark reddish-brown (5YR 2/2 moist) silty loam; few, fine, faint yellowish-red (5YR 5/8 moist) redox mottles; weak moist consistence; apedal, massive structure; 2% subrounded ferruginous ironstone gravel fine-sized; moderate permeability, slow dispersion; pH 6.4; EC 2mS/m; clear, smooth boundary
50–80	Dark-brown (7.5YR 3/2 moist) sandy gravel texture; moist soil; apedal, massive structure; 40% subrounded ferruginous ironstone gravel fine-sized and 20% subrounded ferruginous ironstone gravel medium-sized; moderately rapid permeability; pH 6.5; EC 2mS/m; weakly clayey fine sand; gradual, smooth boundary
80–100	Very dark-grey (7.5YR 3/1 moist) clay with many fine, distinct, yellowish-red (5YR 4/6 moist) redox mottles; moist soil; apedal, massive structure; indeterminate fabric; slickensides; 5% subrounded ferruginous ironstone gravel fine-sized and 15% subrounded ferruginous ironstone gravel medium-sized; slow permeability, rapid dispersion; pH 6.7; EC 4mS/m; gradual, smooth boundary
100–140	Dark reddish-brown (5YR 3/2 moist) heavy clay; very firm moist consistence, slightly sticky, very plastic; apedal, massive structure; very slow permeability, slow dispersion; pH 6.6; EC 8mS/m; diffuse, irregular boundary
140–200	Dark olive–grey (5Y 3/2 moist) heavy clay; moist soil, slightly sticky, very plastic; apedal, massive structure; very few medium, unidentified soft segregations; very slow permeability, non-dispersing; pH 7.4; EC 10mS/m
200–230+	Dark olive–grey (5Y 3/2 moist) heavy clay; moist soil, slightly sticky, very plastic; apedal, massive structure; few medium, unidentified soft segregations; very slow permeability, non-dispersing; pH 8.1; EC 15mS/m

Chemical analysis

Depth (cm)	Texture	CF%	Clay	Silt	Sand	pH	Al_CaCl$_2$	EC (mS/m)	OC_wb	K_HCO$_3$	P_HCO$_3$	P_kjel	PRI	CEC_	Exch_Ca	Exch_K	Exch_Mg	Exch_Na	ESP	Exch_Al
0–10	L	3	10	9	81	4.6	1	20	4.06	519	106	1920	173	11.0[a]	5.69	0.90	3.29	1.14	10	0.39
10–30	SCL	11	15	8	77	4.9	1	6	0.76	350	59	2008	85	10.4[a]	3.39	0.63	5.00	1.35	13	0.27
30–50	ZL	35	17	8	76	4.9	1	5	0.53	355	63	2026	86	15.0	2.39	1.07	5.46	1.26	10	
50–80	GR	56	9	2	89	5.0	1	4	0.24	331	47	1341	35	12.0	1.68	0.96	4.31	1.02	11	
80–100		54	45	3	52	5.4	1	13	0.20	550	76	2359	141	22.0	3.03	1.59	9.07	3.43	18	
100–140	HC	0	36	5	59	5.6		22	0.15	673	64	2037	15	31.0	5.04	1.84	14.40	4.97	18	
140–200	HC	0	47	7	47	6.2		45	0.10	892	56	2977	21	40.0	8.32	2.86	22.50	9.20	22	
200–230	HC	0	45	6	49	7.8		44	0.08	1000	55	5946	48	39.0	7.43	2.18	19.18	8.20	22	

a Values have been estimated or inferred from related observations or measurements.

Appendix F Distribution of LMUs in soil-landscape subsystems

Table F1 Percentage distribution of land management units (LMUs) in soil-landscape subsystems

Map unit	Area (ha)	Land management unit														
		Good coloured sands	Good gravels	Good heavy soils	Good loams	Good sandy duplexes	Fair coloured sands	Fair pale sands	Poor clays, loams and duplexes	Poor coloured sands	Poor gravels	Poor pale sands	Saltland	Shallow soils	Unsuitable landform	Very shallow or rocky soils
222Ag_1c	34												100			
222Ag_5a	454						18			50		20	0		12	
222Ag_5d	156						5			10		20	10		55	
222Co_1	363				3	2	5			20		68		2		
222Co_3a	470		20				10				31	29				10
222Co_3c	57		35	30				5		5	5	10		10		
222Co_5a	3877		15				8	5		17	15	25		15		
222Co_6a	3446	5	5			5	35	15		15		20				
222Co_6b	47	15	10	10			22	20	10			10			3	
222Co_6c	111							20		30		50				
222Cp_1a	109		40							5	10	25		10		10
222Cp_2a	640	15	5			5	20	15	5	20		5	5		5	
222Cp_4b	17	70	30													
222Cp_5c	2175	10					30			40		20				
222Cp_6a	675						20			5		55			20	
222Cp_6c	49											10		10	80	
222Cp_7d	267												1		99	
222Da_1a	894	18	41				19			2		5				15
222Da_1b	52	20	40		20											20
222Da_1c	88				50				10					10		30
222Da_1d	4154	35	15		5		10			5		5		5		20

(continued)

Table F1 continued

Map unit	Area (ha)	Land management unit														
		Good coloured sands	Good gravels	Good heavy soils	Good loams	Good sandy duplexes	Fair coloured sands	Fair pale sands	Poor clays, loams and duplexes	Poor coloured sands	Poor gravels	Poor pale sands	Saltland	Shallow soils	Unsuitable landform	Very shallow or rocky soils
222Da_1e	117		40									40				20
222Da_2a	7363	17	3				32	8		25		6		9		
222Da_2b	655						10	20		40		30				
222Da_3	9970	54	5		5	2	12			9		6		5	2	
222Da_4a	818	13	3	14	29	20	3							13	5	
222Da_4b	34		20	48	10								2	10		10
222Da_5	64				10									80		10
222Da_6	567	35	10		20	10									25	
222Da_7a	747	20					45					25			10	
222Da_7b	368						15								85	
222Da_8a	515				5		5						5		85	
222Da_9	22														100	
222Rw_1a	865	40	5			5	25	5		20						
222Rw_1b	1007	15	5				31			29		20				
222Rw_2	2051		33				12	15			5	20		5		10
222Rw_3a	6909	15	18				40			20		7				
224Bh_3	22		40	24		12		10			5			5	2	2

Note: Map unit codes are explained in Appendix B.

Shortened forms

Short form	Long form
ASC	Australian Soil Classification
$CaCl_2$	calcium chloride
cm	centimetre
DPIRD	Department of Primary Industries and Regional Development
EC	electrical conductivity
GDA94	Geodetic Datum of Australia 1994
GIS	geographic information system
LMU	land management unit
m	metre
mm	millimetre
mS/m	millisiemens per metre
NRInfo	Natural Resource Information mapping portal, https://www.agric.wa.gov.au/resource-assessment/nrinfo-western-australia

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