Adani Mining Pty Ltd

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Carmichael Coal Mine and Rail Project SEIS

Report for **Rail Soil Survey Methodology**

24 July 2013

GHD

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Abbreviations

Abbreviations	Meaning
AHD	Australian Height Datum
ALC	Agricultural Land Class
ASC	Assessment of Site Contamination
ASS	Acid Sulfate Soil
ASPAC	Australian Soil and Plant Analysis Council
CEMP	Construction Environmental Management Plan
CLR	Contaminated Land Register
CPSS	Certified Professional Soil Scientist
DBYD	Dial Before You Dig
DNRM	Department of Natural Resources and Mine
DSDIP	Development, Infrastructure and Planning
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EMR	Environmental Management Register
EIS	Environmental Impact Statement
EP Act	Environmental Protection Act 1994
EPBC	Environment Protection and Biodiversity Conservation Act
ESCP	Erosion and Sediment Control Plan
GBRMP	Great Barrier Reef Marine Park
GQAL	Good Quality Agricultural Land
NATA	National Association of Testing Authorities
NEPM	National Environmental Protection Measures
SAP	Sampling and Analysis Plan
SCL	Strategic Cropping Land
SMP	Site Management Plan
SQP	Suitably Qualified Professional
SWS	Soil Water Storage
UMA	Unique Mapping Areas

1. Introduction

1.1 Project overview

Adani Mining Pty Ltd (Adani, the Proponent), commenced an Environmental Impact Statement (EIS) process for the Carmichael Coal Mine and Rail Project (the Project) in 2010. On 26 November 2010, the Queensland (Qld) Office of the Coordinator General declared the Project a 'significant project' and the Project was referred to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (referral No. 2010/5736). The Project was assessed to be a controlled action on the 6 January 2011 under section 75 and section 87 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The controlling provisions for the Project include:

- World Heritage properties (sections 12 & 15A)
- National Heritage places (sections 15B & 15C)
- Wetlands (Ramsar) (sections 16 & 17B)
- Listed threatened species and communities (sections 18 & 18A)
- Listed migratory species (sections 20 & 20A)
- The Great Barrier Reef Marine Park (GBRMP) (sections 24B & 24C)
- Protection of water resources (sections 24D & 24E)

The Qld Government's EIS process has been accredited for the assessment under Part 8 of the EPBC Act in accordance with the bilateral agreement between the Commonwealth of Australia and the State of Queensland.

The Proponent prepared an EIS in accordance with the Terms of Reference (ToR) issued by the Qld Coordinator-General in May 2011 (Qld Government, 2011). The EIS process is managed under section 26(1) (a) of the *State Development and Public Works Act 1971* (SDPWO Act), which is administered by the Qld Government's Department of State Development, Infrastructure and Planning (DSDIP).

The EIS, submitted in December 2012, assessed the environmental, social and economic impacts associated with developing a 60 million tonne (product) per annum (Mtpa) thermal coal mine in the northern Galilee Basin, approximately 160 kilometres (km) north-west of Clermont, Central Queensland, Australia. Coal from the Project will be transported by rail to the existing Goonyella and Newlands rail systems, operated by Aurizon Operations Limited (Aurizon). The coal will be exported via the Port of Hay Point and the Point of Abbot Point over the 60 year (90 years in the EIS) mine life.

Project components are as follows:

- The Project (Mine): a greenfield coal mine over EPC 1690 and the eastern portion of EPC 1080, which includes both open cut and underground mining, on mine infrastructure and associated mine processing facilities (the Mine) and the Mine (offsite) infrastructure including a workers accommodation village and associated facilities, a permanent airport site, an industrial area and water supply infrastructure

- The Project (Rail): a greenfield rail line connecting to mine to the existing Goonyella and Newlands rail systems to provide for the export of coal via the Port of Hay Point (Dudgeon Point expansion) and the Port of Abbot Point, respectively including:
  - Rail (west): a 120 km dual gauge portion running west from the Mine site east to Diamond Creek
  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah
  - Quarries: The use of five local quarries to extract quarry materials for construction and operational purposes

1.2 Report purpose

This report has been prepared as part of the Supplementary Environmental Impact Statement (SEIS) for the proposed Carmichael Coal Mine and Rail Project. This report provides a soil survey methodology based on the Terms of Reference (ToR), the Soils and the Environmental Impact Statement (GHD, 2012), and the *Report for Strategic Cropping Land Assessment* (GHD, 2013), which was prepared for submission in the SEIS. A ToR requirement is for a soil survey to be undertaken of the impacted areas associated with the development of the project.

The objective of this document is to provide a staged soil survey methodology for the assessment of the proposed Project (Rail) corridor, ancillary infrastructure and quarries, to allow Adani and their contractors to undertake construction, rehabilitation and operation phases of the Project. Reporting requirements have been detailed according to relevant soil survey methodologies, and a schedule of timing proposed to deliver reports in advance of key milestone dates.

Soil sampling will be undertaken only on areas to be impacted by development and construction and is exclusive of areas not impacted by these activities. The soil survey sampling will adhere to principles of a free survey rather than sampling at regimented locations.

It is not an intention of this soil survey for each site visited as part of the soil survey to be described in detail with laboratory analysis. Soil surveys use a combination of different site descriptions, which vary in the level of detail captured. These combinations are presented in Section 4 for linear surveys (rail only) and Section 7 for non-linear surveys (ancillary infrastructure and quarries) to establish soil types and boundaries.

This methodology report is applicable to both the Rail (west) and Rail (east), ancillary infrastructure and quarries as detailed in the study area explained in Section 1.3.

1.3 Study area

The study area for this methodology relates to the Project (Rail), inclusive of the associated ancillary infrastructure, quarries and rail corridor. The Project (Rail) consists of a 95 metre (m) corridor referred to as:

- Rail (west): a 120 km dual gauge portion running west from the Mine site east to Diamond Creek
- Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah

In addition to the 95 m wide rail corridor the following is also included in the study area:

- The ancillary infrastructure (bridge laydowns, track laydowns, turning circle laydowns, construction depot, concrete batching plant locations, construction camps and maintenance facility locations) will be located outside of the 95 m rail corridor.
- There are a total of five quarries, identified as Disney, Borrow 7, Back Creek South, Moray Quarry and North Creek, which have been positioned within the region to facilitate the sourcing of construction materials for the project.

2. Methodology key points

2.1 Overview

The soil survey methodology has been developed to enable the above objectives identified in section 1.2 to be addressed. The soil survey will adopt a range of scales dependent on the environment and the aim of the survey. For all surveys with the exception of any contaminated land assessment (if intrusive sampling is required) will be done using the free survey technique as defined in McKenzie et al. (2008).

Free survey techniques are the conventional and preferred soil survey method in Australia and account for landscape complexity, whereby sampling locations are selected when in the field to represent differentiation in landscape attributes, ground observations and vegetation. Such a methodology facilitates aggregation of similar soil types and landscapes into soil units or unique mapping areas (UMA), which can be mapped accordingly and allows identification and segregation of problematic soils. Development of management procedures can then be presented based on those UMA that are established through this survey.

Available information pertaining to existing soil and landscape information, rail engineering design, legislation and guidelines has been reviewed to tailor the soil survey methodologies relative to the project.

Following this review it was identified that there are varying soil survey requirements depending on the information to be collected, the type of disturbances and the intent of the assessment. The following have been identified as the key assessment items for the study area:

- General soil survey to inform management procedures and rehabilitation
- Assessment of the impact on Good Quality Agricultural Land (GQAL)
- Assessment for the presence of contaminated land
- Assessment of ancillary infrastructures
- Assessment of quarries
- Validation of existing 1:100,000 mapping

A soil survey methodology has been developed for each of the above which details principles justifying the need for conducting surveys, mapping scale, intensity of ground observations, sample methodology and requirements. Distribution of the required soil surveys are provided in Figure 1. Flexibility exists in sample site selection, with a higher sampling intensity required in more complex landscapes and lower sampling intensity sufficient for more uniform landscapes. Though mapping density may vary across the Project (Rail), the overall intensity will range between 1:50,000 and 1:100,000 scale.

The type of ground observations used throughout the survey will differ depending on the information already captured, the uniformity or complexity of the landscape, and the type of disturbances that are likely to occur. In more uniform landscapes, ground observations may be sufficient validation at intervals of 500 m and 1000 m. It is not intended for each ground observation to be a detailed assessment with laboratory testing. The breakdown of the ground observation requirements are detailed in Section 4 for linear surveys (rail corridor) and Section 7 for non-linear (area surveys for ancillary infrastructure and quarries).

Following the soil survey, soil-related environmental values, conditions, associated impacts and mitigation measures will be presented in key deliverables, which will be developed so as to be incorporated into the Environmental Management Plans and procedures. Key deliverables that will be produced or may benefit from the soil surveys may include but are not limited to:

- Construction Environmental Management Plan (CEMP)
- Detailed Erosion and Sediment Control Plan (ESCP)
- Soils Management Plan
- Rehabilitation Management Plan

2.2 Relevant legislation and guidelines

This methodology has been developed according to the following legislation and guidelines. These documents are applicable to the planning, approval, construction and operation of the Project in relation to soils and soil management.

- *Environmental Protection Act 1994*
- State Planning Policy 1/92 Development and the Conservation of Agricultural Land
- Planning Guidelines: The Identification of Good Quality Agricultural Land 1993
- National Environment Protection (Assessment of Site Contamination) Amendment Measure 1999 (No. 1)),
- DEHP. 2012. Guideline for contaminated land professionals. Brisbane: Department of Environment and Heritage Protection, Queensland Government. October 2012.

The soil survey methodology has been developed with reference to the following guidelines:

- Australian Soil and Land Survey: Guidelines for Survey Soil and Land Resources (McKenzie et al., 2008)
- Land Suitability Assessment Techniques (DME, 1995)
- Australian Soil Classification (Isbell, 2002)
- Australian Soil Survey and Land Survey Field Handbook (National Committee on Soil and Terrain, (NCTS) 2009)
- Assessment and Management of Contaminated Land in Queensland (DoE, 1998)
- Planning Guidelines: the Identification of Good Quality Agricultural Land. Department of Primary Industries and Department of Housing, Local Government and Planning Queensland, (DPI/DHLGP, 1993)
- DEHP (2012) Guideline for contaminated land professionals. Brisbane: Department of Environment and Heritage Protection, Queensland Government. October 2012.
- DERM (2011). Draft for Discussion, Soil Survey for Linear Features, Queensland Government. Department of Environment and Resource Management

2.3 Soil survey assessments

2.3.1 General soil assessment

The initial and overriding need for a soil survey is to identify the soil types and distributions within the project area at a scale that will allow management measures to be effectively implemented throughout construction and rehabilitation. This is to be achieved by the following:

- Identification of the different soil types that will require special attention and the development of appropriate management strategies for inclusion into relevant management plans. Examples include but are not limited to:
  - Cracking clays which have the potential to impact construction schedules due to trafficability hindrances during wet weather
  - Dispersive and unstable soils which require additional provisions for the design of drainage structures and for erosion and sediment control management
  - Saline soils which will be typically unsuitable for use in rehabilitation
  - Acidic or sodic soils that may require amelioration and management prior to rehabilitation
- Identification of the different land systems that will require special attention and the development of appropriate management strategies. Examples include:
  - Low lying areas prone to seasonal water logging. These areas have the potential to impact construction schedules due to trafficability / workability hindrances whilst wet.
  - Permanent and ephemeral water courses and drainage lines that require constructability consideration for erosion and sediment control during construction
  - Areas where moderately inclined to steep lands are present, and / or are typified by a high erosion potential that may be impacted on by the construction process, and impact the environmental performance of the project

An assessment of good quality re-usable topsoil or subsoil material is vital for the rehabilitation phase of the Project, as is identification of poor quality topsoil and subsoils requiring amelioration for use in rehabilitation.

The intensity of ground observations will be conducted in reference to '*Guidelines for Surveying Soil and Land Resources'* (McKenzie et al., 2008), The proportion of ground observation classes will be as per that recommended in the '*Guidelines for Surveying Soil and Land Resources'* (McKenzie et al., 2008), taking into consideration also the unpublished '*Draft for discussion – soil survey methodology along linear features'* (Forster, 2011).

2.3.2 Good Quality Agricultural Land (GQAL)

The agricultural value of land disturbed by the Project (Rail) will be assessed by completing an assessment of mapped good quality agricultural land (GQAL) within the study area. GQAL will be surveyed at a scale of 1:50,000. Assessing the agricultural values of land is important to inform the Proponent, regulators, and the community of existing agricultural land uses that could potentially be impacted on by the Project (Rail). It is expected that this information will have a strong influence on rehabilitation standards and management.

2.3.3 Contaminated land

Contaminated land refers to land contaminated by hazardous substances which may pose a risk to human health or the environment. Land contamination can occur as a result of poor environmental management and waste disposal practices or accidental spills in industrial or commercial activities. In the past, land has been contaminated by activities not known to be dangerous at the time, often involving chemicals which have since been banned or are now subject to much stricter controls.

A desktop assessment (confined to a search of the Environmental Management Register (EMR) and Contaminated Land Registers (CLR) for the rail corridor only) was undertaken during the EIS phase of the project, which identified the one property listed on the EMR, Lot 637 on PH1980, is listed on the EMR for a Livestock Dip or Spray Race. This one identified property does not mean there are no other potentially contaminating activities within the study area inclusive of the ancillary infrastructure and Quarries.

In addition to any soils assessments, further desktop assessment as well as stakeholder consultation will be required to further assess potential contaminated land, in order to inform any on-ground assessments. The contaminated land investigation will not require soil testing unless justified following further desktop assessment and ground-truthing.

2.3.4 Ancillary infrastructure

Additional soils investigations may be required for ancillary infrastructure depending on the type of disturbances that will occur. Such disturbances may relate to potential effluent irrigation areas associated with temporary construction camps, laydown areas, borrow pits, temporary access tracks and turning circles.

Soil surveys for ancillary infrastructure and quarries are based on an ‘area’ survey as opposed to a ‘linear’ survey approach for the rail alignment. The level of detail required to be captured will vary depending on the disturbances occurring, proximity to soils information collected for the rail alignment, and whether the land forms and soil types are different to that identified along the rail corridor.

2.3.5 Quarries

Five sites have been identified for the construction of quarries in the vicinity of the Project (Rail). It is recommended that soil surveys be conducted on proposed quarry sites to develop topsoil stripping, topsoil re-use, inform erosion and sediment control planning, and any rehabilitation management plans.

2.3.6 Existing 1:100,000 mapping

Where existing detailed mapping at a scale of 1:100,000 or better is present (confined to Rail (east) specifically CH20 to CH0) a less intrusive investigation is proposed, with the method of assessment being validation of the existing mapping dataset. This does not remove the requirement to undertake field work, but it allows for a confirmatory assessment of these areas already surveyed. Within areas mapped already at 1:100,000, each mapped soil unit will be verified to ensure the boundaries and characteristics are as reported with less laboratory testing being undertaken than other areas with more broad scale mapping available.

2.4 Non-relevant soil assessment

2.4.1 Strategic cropping land

A validation assessment of Strategic Cropping Land (SCL) will not be required to be undertaken due to the preference for Adani to accept the SCL trigger mapping as it currently stands, for those properties which have an observable History of Cropping. This assessment is reported separate to this document. For the potential SCL within properties that do not have the required history of cropping, no assessment will be required of the SCL if DNRM accept the validation assessment, which will be submitted separate to the SEIS.

2.4.2 Acid sulfate soils

The State Planning Policy 2/02: Planning and Management of Development Involving Acid Sulfate Soils states that ASS occurs along coastal areas, generally where land elevation is less than 5 m AHD. However, ASS is known to also occur in some inland areas within river and lake beds, irrigation channels and in saline seepage areas. The Australian Soil Resource Information System (www.asris.csiro.au) for ASS was reviewed. Based on information in the ASS Atlas, there is an extremely low probability of encountering ASS within the study area and an assessment methodology for ASS is not required.

3. Field program

3.1 Timings

Construction of the Project (Rail) is anticipated to commence from April 2014 following the 2013 / 2014 wet season. Timing and scheduling outlined in this section of the report addresses construction activities related only to Rail (west) due to the uncertain route of rail continuation to the Queensland National rail system; however, all methodology details and requirements are applicable to Rail (east). Inclusive within both the east and west areas, is the associated ancillary infrastructure and quarries.

Construction of the Rail (west) and associated infrastructure and quarries will be undertaken in a four stage approach across four construction “fronts” (Table 1). Rail (east) soil surveys would be undertaken in a similar manner, but not presented here due to the construction staging and timing commencing at Rail (west). The reporting of the soil survey results is required to be undertaken prior to commencement of particular activities, as detailed in Table 2.

The soil surveys will need to be completed in advance of the mobilisation and site establishment to ensure all relevant information regarding soils is known and understood prior to any site disturbances, and incorporated in the Construction Environmental Management Plan (CEMP) and Soil Management Plan. It is proposed that soil surveys be staggered according to the four stages outlined in Table 2 (for the Rail West and associated ancillary infrastructure) and to inform the site design and establishment with regards to erosion and sediment control planning, topsoil stripping, access track development and management of temporary disturbances via the CEMP.

In order to provide consistency with the broader construction planning for the project, a soil survey will be undertaken and reported on within each of the four fronts. This will ensure that each front and each construction team has a specific soils report / mapping tailored specifically to those areas. Table 1 provides a broad overview of the four fronts of Rail (west).

Table 1 Front extents

Front	Approximate chainage start	Approximate chainage finish
Front 1	Commencing at chainage 98.5 km	Culminating at chainage 65.5 km
Front 2	Commencing at chainage 98.5 km	Culminating at chainage 125 km
Front 3	Commencing at chainage 148 km	Culminating at chainage 125 km
Front 4	Commencing at chainage 148 km	Culminating at chainage 183 km
Rail (east)	Commencing at Chainage 65.5 km	Culminating at chainage 0 km.

Details of the key deliverables that will be produced from these assessments are detailed in Section 1 of this document. It is likely that these reports will be required to obtain relevant State approvals, which is particularly the case for the GQAL as this is administered under State Planning Policies.

The construction program has been divided into four main stages of construction:

1. Enabling works (April 2014 to June 2014)
2. Earthworks and structures (June 2014 to September 2016)
3. Tracklaying (June 2015 to September 2016)

4. Signalling and Communications (December 2015 to December 2016)

It is noted that these dates are subject to change. The level of soil assessments required for each main stage of the construction program is presented in Table 2.

Table 2 Proposed stages of Rail construction

Stage	Start Date	Completion Date	Works associated with Soil Surveys	Key activities to be completed or commenced
Enabling activities	April 2014	June 2014	Preparation of four camp areas and associated infrastructure Quarry approvals Staged site clearing, grubbing and topsoil removal	Development of Soil Management Plan, Erosion and Sediment Control Plan, Rehabilitation Management Plan and Further assessment of contaminated land included both desktop and ground truthing exercises. Development of Sampling Analysis Plan Soil surveys and associated reporting to be conducted for rail, ancillary infrastructure, quarries and any contaminated land identified in the desktop assessment and ground truthing.
Earthworks and Structures	June 2014	September 2015	Camp construction Staged site clearing, grubbing and topsoil removal Light vehicle / delivery access and haul roads Laying of construction communications cabling Installation of construction water pipelines, holding dams and delivery systems Localised earthworks Hardstand construction Drainage culverts Bridge piling and construction Bulk earthworks Construction of the Flash Butt Welding Yard	Continuation of soil surveys and associated reporting to be conducted. Monitoring performance against CEMP and Soil Management Plan Progressive rehabilitation to be undertaken
Track laying	June 2015	September 2015	Track laying activities	Progressive rehabilitation

Stage	Start Date	Completion Date	Works associated with Soil Surveys	Key activities to be completed or commenced
Signalling and Communications	May 2015	December 2015	Construction of all signalling assets, including laying of optical fibre cable, fixing points machines, junction boxes, way side equipment and communication towers, signals, etc.	Continuation of soil surveys and associated reporting to be conducted. Monitoring performance against CEMP and Soil Management Plan Progressive rehabilitation to be undertaken

3.2 Mapping scale and ground observation intensity

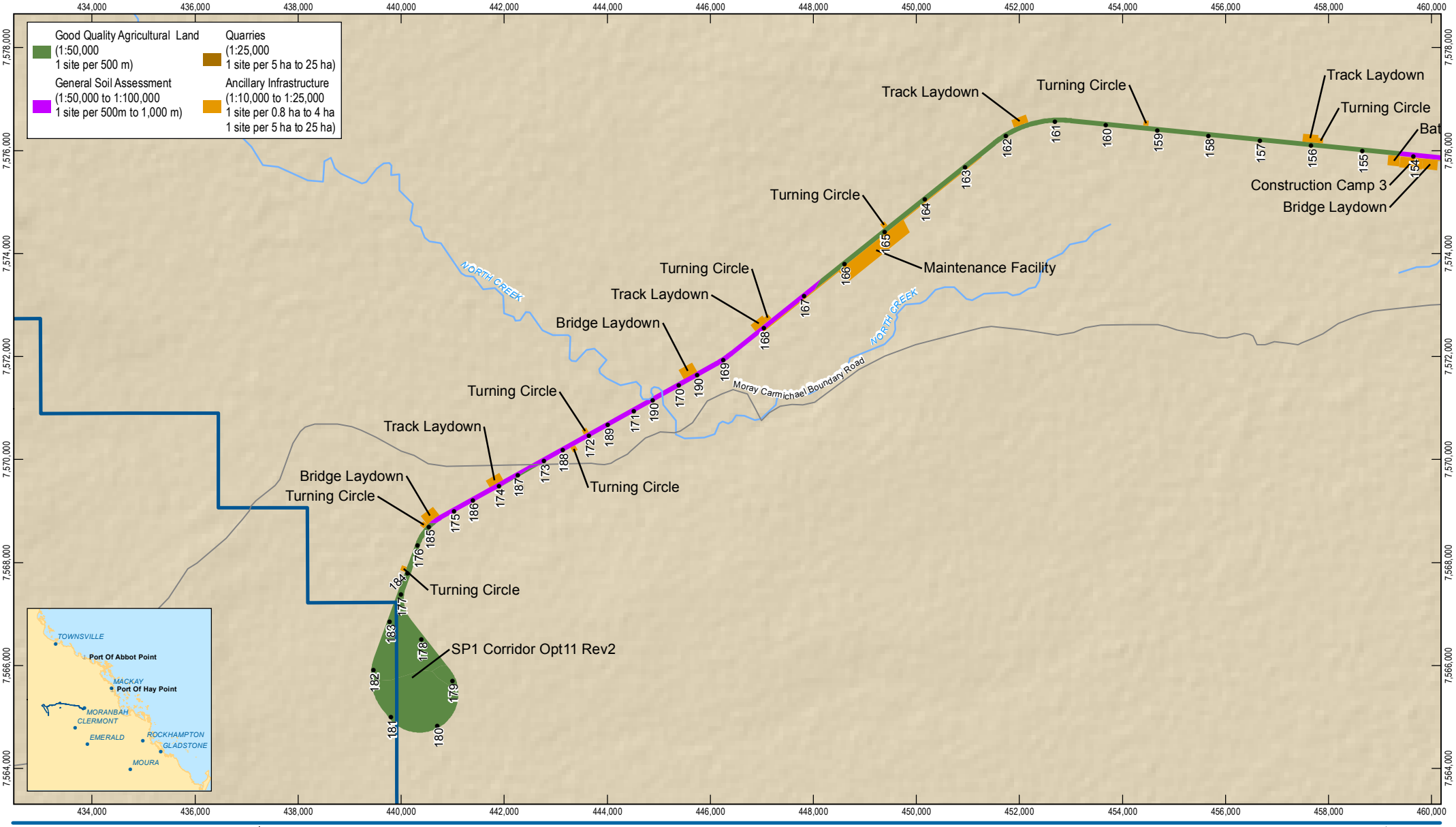
All areas with the exception of GQAL, contaminated land, ancillary infrastructure and quarries will be surveyed at a scale of 1:50,000 to 1:100,000 (depending on the landscape complexity). The intensity of ground observations is related directly to scale. The intensity for ground observations is included in Table 3.

Table 3 Ground observation intensity

Soil survey aim	Mapping scale	Ground observation density	Section within document
General Soil Assessment	1:50,000 to 1:100,000	1 site per 500 – 1,000 m[1]	Section 4
Good Quality Agricultural Land	1:50,000	1 site per 500[1] m	Section 5
Contaminated Land	NA	To be established following detailed desktop and ground-truthing exercise.	Section 6
Ancillary Infrastructure	1:10,000 to 1:25,000	1 site per 0.8 – 4 ha to 1 site per 5 ha to 25 ha	Section 7
Quarries	1:25,000	1 site per 5 ha to 25 ha	Section 7
Validation of existing 1:100,000 mapping	1:100,000	1 site per UMA identified in the 1:100,000 mapping	Section 8

The various aims of the soil survey require different approaches to the density, type of information to be captured in separate methodologies. Distribution of the required soil surveys are provided in Figure 1.

[1] This is a linear methodology but may deviate from the centreline of the corridor based on differentiation of soil types and land form



1:100,000 (at A4)
0 1 2
Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND
Homesteads
Highway
Main Road
Secondary Road
Local Road
Railway
Watercourse (Major)
Project (Mine)

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Date 30-07-2013

Soil Survey Density - Sheet 1

Figure 1

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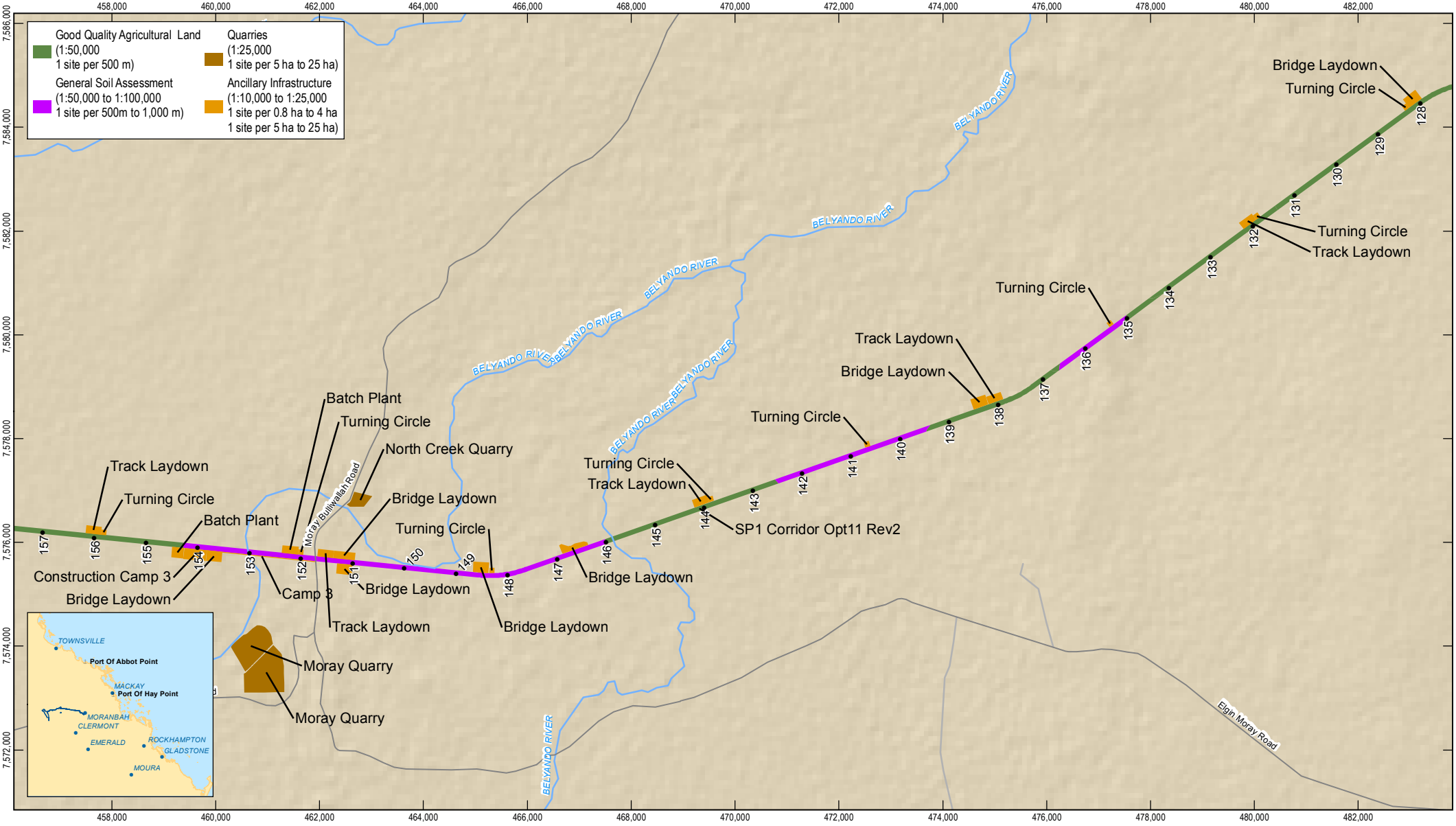
Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: Sp1 and 2 Corridor 01/07/13,Quaries, Ancillary Features 01/07/13; DNRM: Roads/2013. Created by IH



1:100,000 (at A4)
0 1 2
Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND
Homesteads
Secondary Road
Railway
Project (Mine)
Highway
Local Road
Watercourse (Major)
Main Road

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Soil Survey Density - Sheet 2

Figure 1

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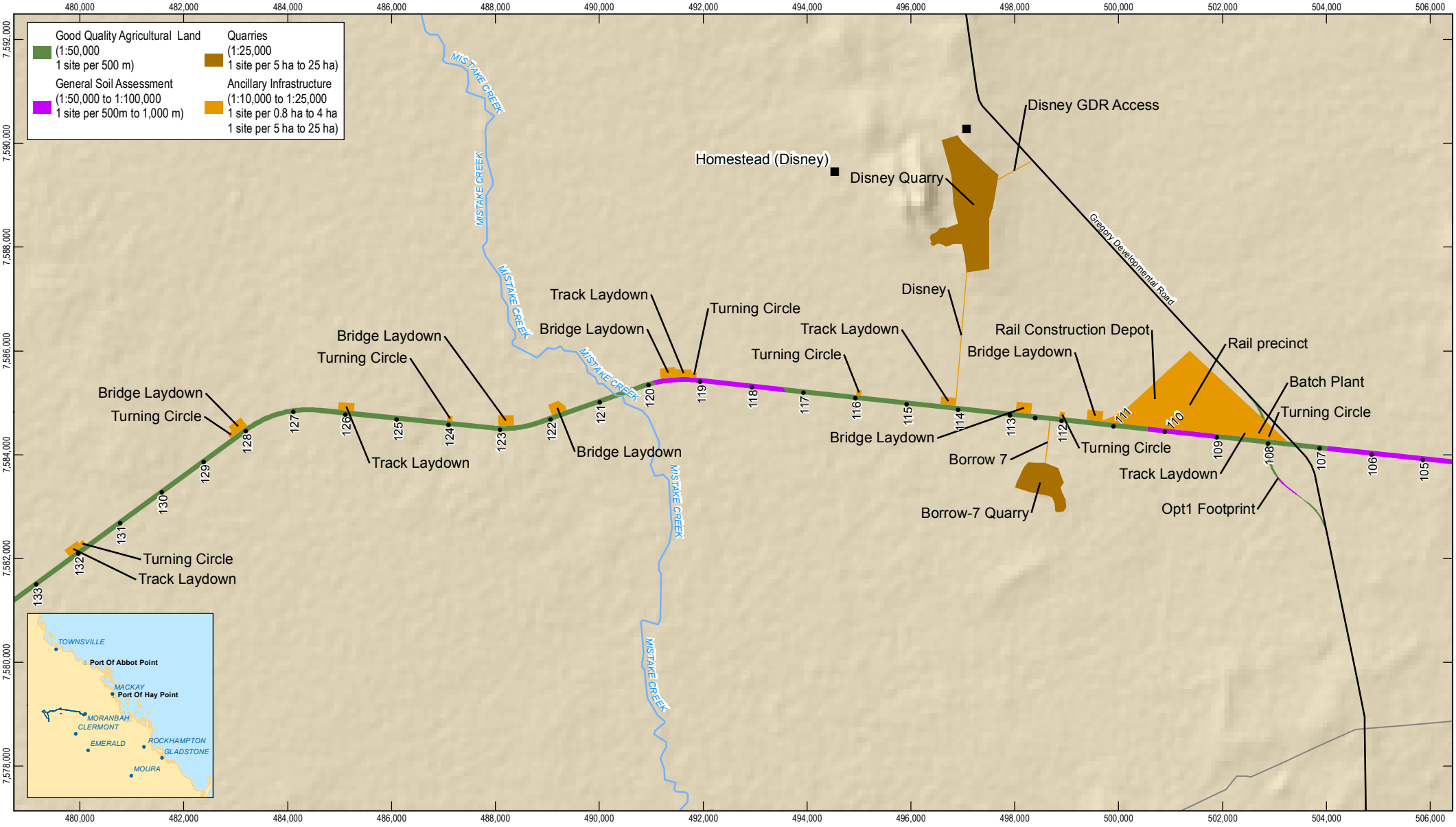

1:100,000 (at A4)

0 1 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Homesteads
- Secondary Road
- Railway
- Project (Mine)
- Highway
- Local Road
- Watercourse (Major)
- Main Road

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Soil Survey Density - Sheet 3

Figure 1

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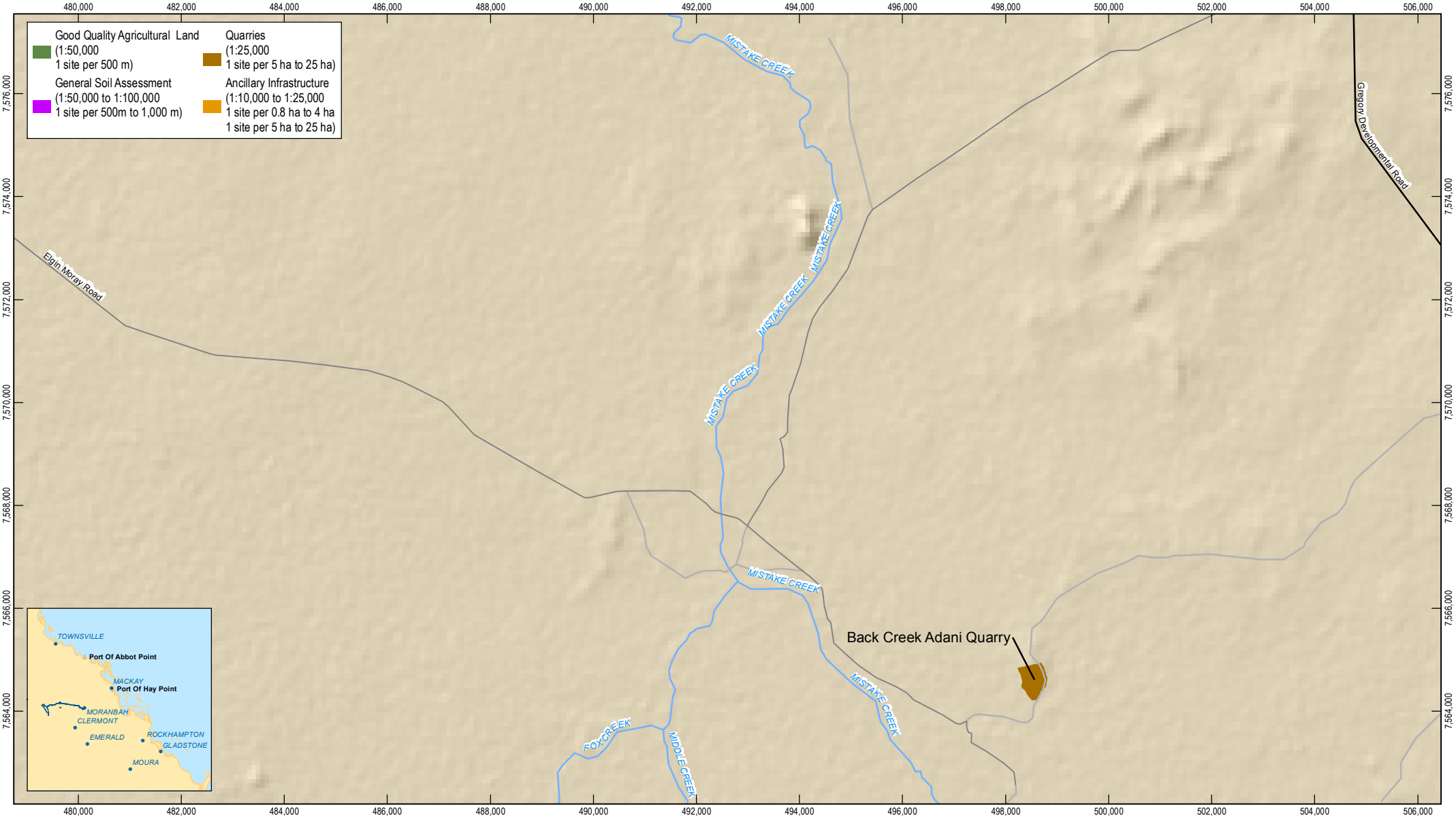

1:100,000 (at A4)

0 1 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Homesteads
- Secondary Road
- Railway
- Project (Mine)
- Highway
- Local Road
- Watercourse (Major)
- Main Road

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Soil Survey Density - Sheet 4

Figure 1

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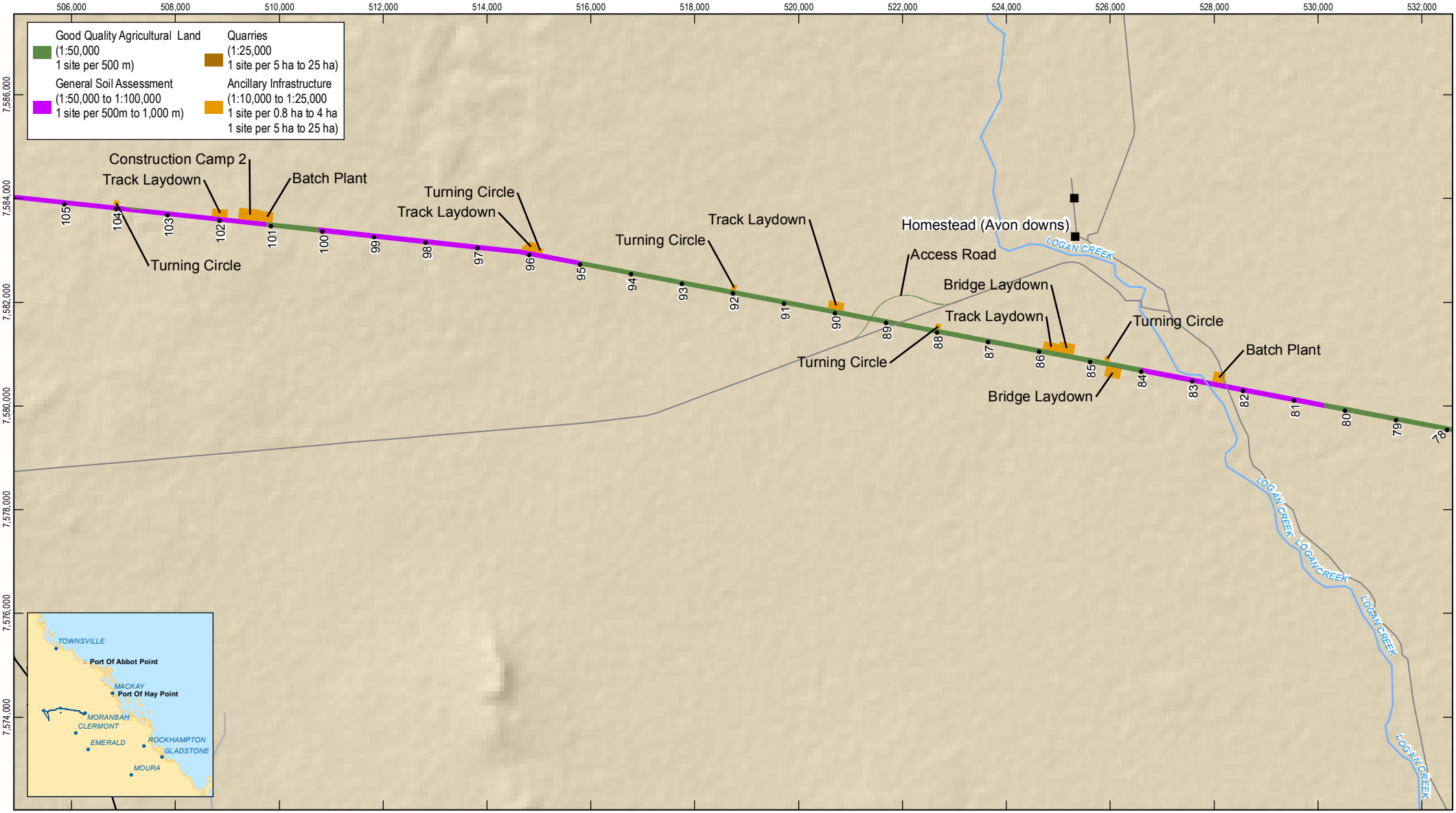

1:100,000 (at A4)

0 1 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Homesteads
- Secondary Road
- Railway
- Project (Mine)
- Highway
- Local Road
- Watercourse (Major)
- Main Road

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Soil Survey Density - Sheet 5

Figure 1

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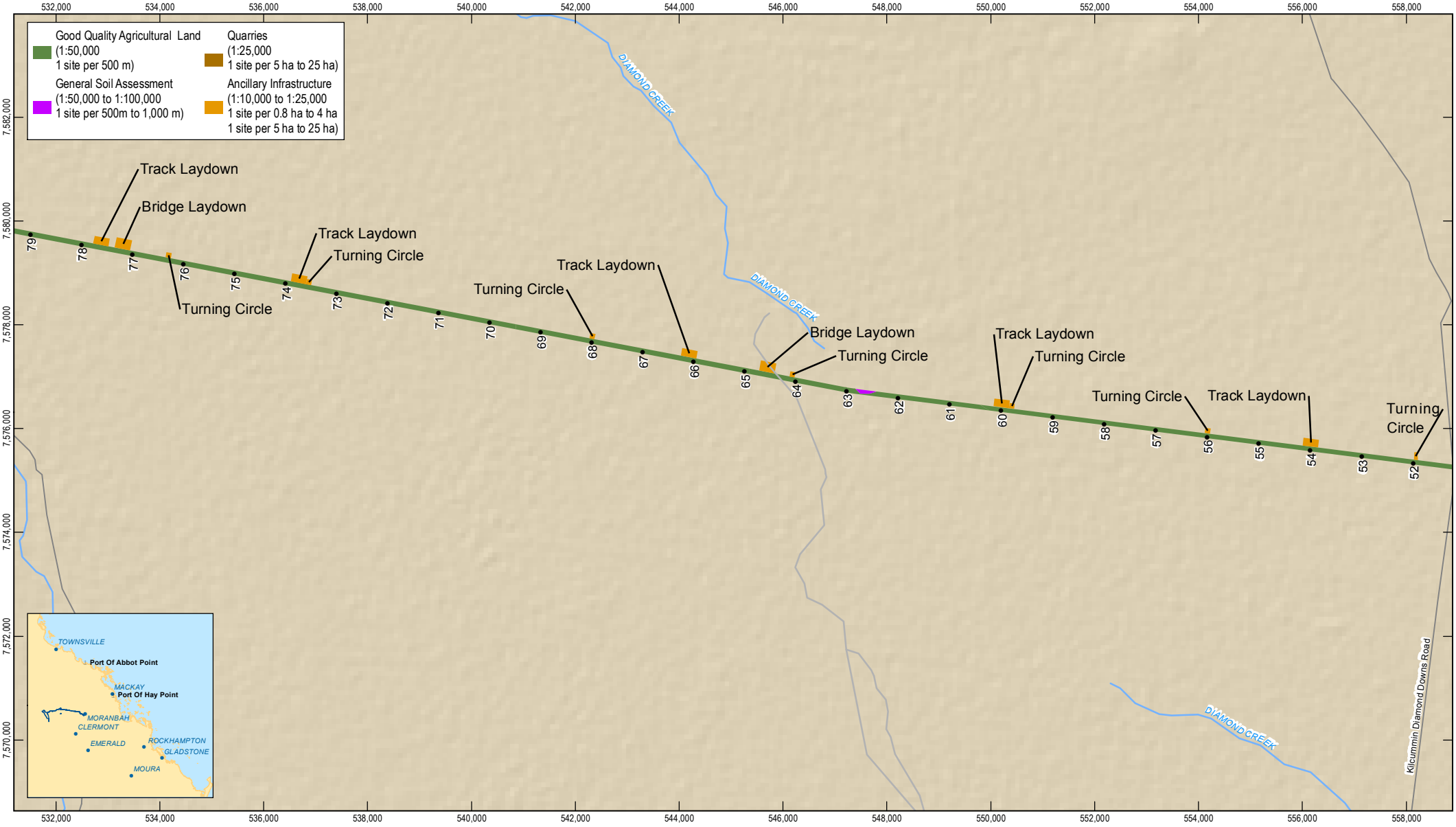
Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: Sp1 and 2 Corridor 01/07/13,Quaries, Ancillary Features 01/07/13; DNRM: Roads/2013. Created by IH



1:100,000 (at A4)

0 1 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Homesteads
- Secondary Road
- Railway
- Project (Mine)
- Highway
- Local Road
- Watercourse (Major)
- Main Road

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	0
Date	30-07-2013

Soil Survey Density - Sheet 6

Figure 1

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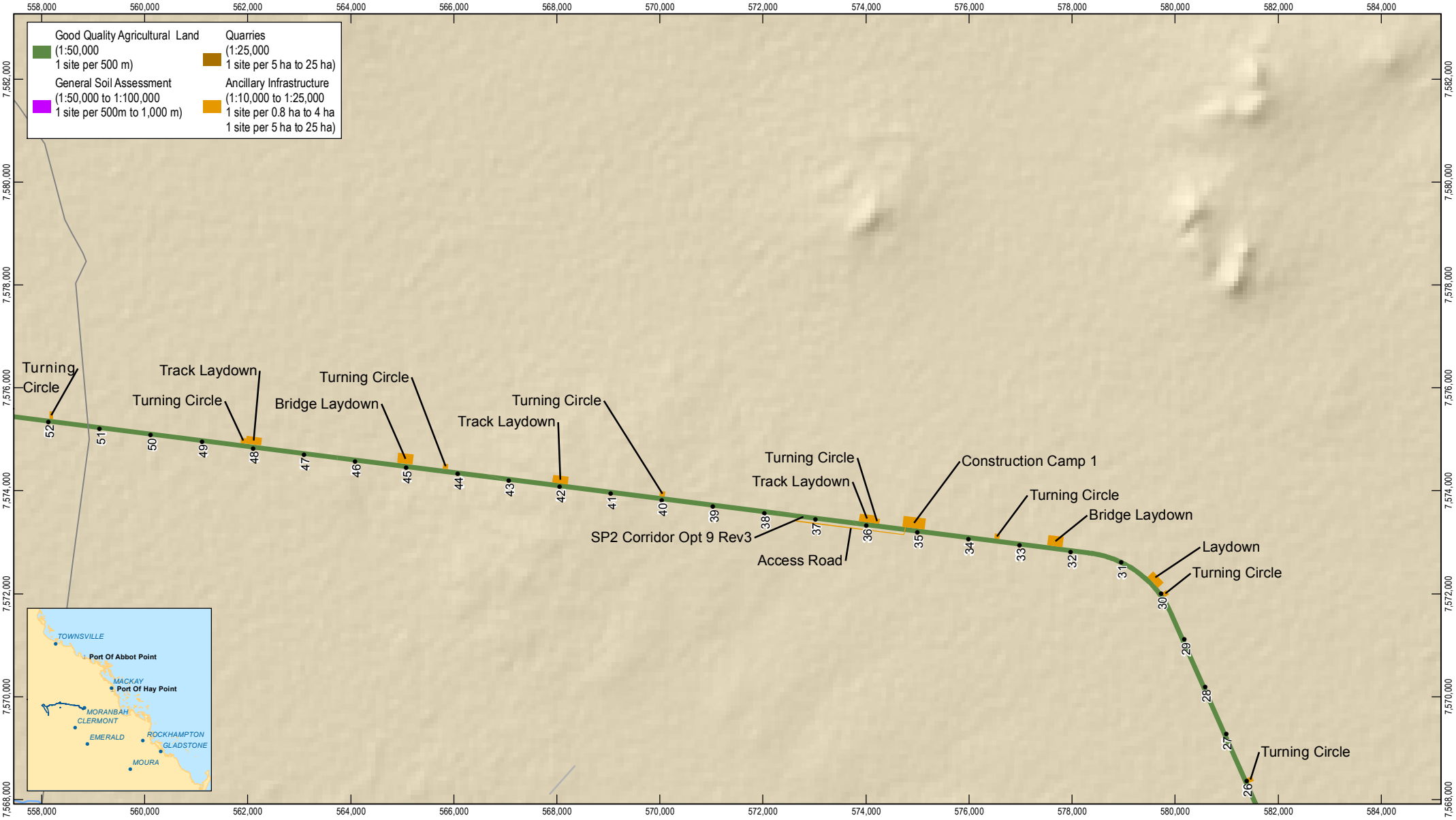
Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: Sp1 and 2 Corridor 01/07/13,Quaries, Ancillary Features 01/07/13; DNRM: Roads/2013. Created by IH



1:100,000 (at A4)

0 1 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Homesteads
- Secondary Road
- Railway
- Project (Mine)
- Highway
- Local Road
- Watercourse (Major)
- Main Road

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision 0
Date 30-07-2013

Soil Survey Density - Sheet 7

Figure 1

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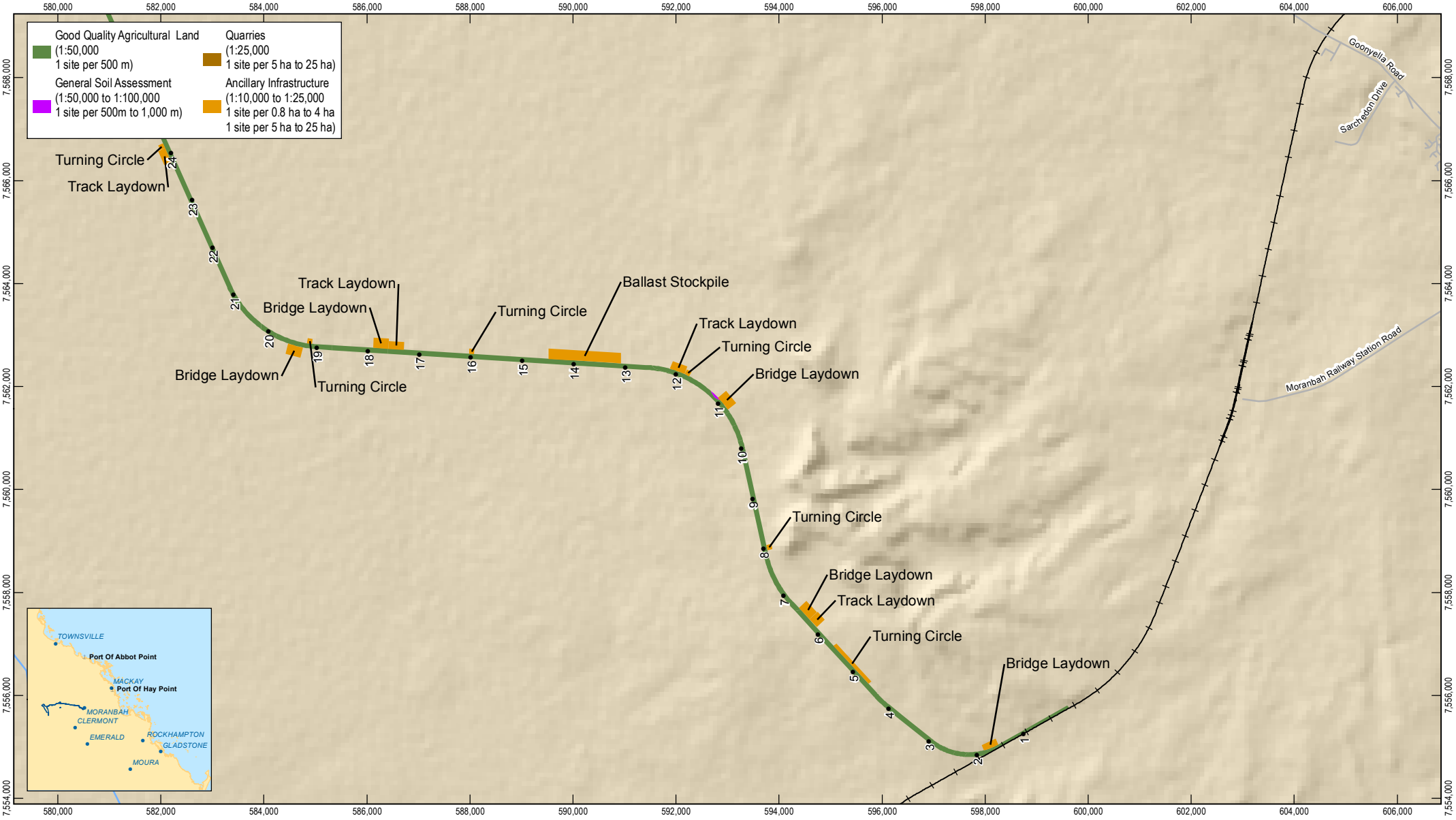
Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: Sp1 and 2 Corridor 01/07/13,Quaries, Ancillary Features 01/07/13; DNRM: Roads/2013. Created by IH



1:100,000 (at A4)

0 1 2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Homesteads
- Secondary Road
- Railway
- Project (Mine)
- Highway
- Local Road
- Watercourse (Major)
- Main Road

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	0
Date	30-07-2013

Soil Survey Density - Sheet 8

Figure 1

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Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: GA: Populated Places, Railway, Watercourse/2007; Adani: Sp1 and 2 Corridor 01/07/13,Quaries, Ancillary Features 01/07/13; DNRM: Roads/2013. Created by IH

3.3 Suitably qualified persons

The soil surveys (general soils assessment, GQAL, ancillary infrastructure and quarries) and reporting will be required to be undertaken by suitably qualified professionals (SQP) in soil surveying. The minimum qualification requirements for professionals conducting soil surveys include:

- Certified Professional Soil Scientist (CPSS) Level 2 competency accreditation in soil survey; and
- Minimum of 5 years demonstrated experience in soil surveying; or
- Each soil report will need to be reviewed and signed off by a CPSS Level 3.

Any contaminated land investigation will be required to be undertaken by person with different qualifications. Sections 381, 395 and 410 of the EP Act require persons who prepare site investigation reports, validation reports and Site Management Plans (SMPs) respectively to be SQPs. To be an SQP, the individual must be a member of a prescribed organisation and have the relevant qualifications and experience in keeping with the Assessment of Site Contamination (ASC) NEPM 2013 and relevant to the contamination issues raised by a particular site. The assessment of contaminated land is a specialised professional area involving a number of disciplines. SQPs must have a range of competencies and be able to recognise the need for supporting professional advice beyond their expertise when assessing contamination and its effects on human health and the environment.

4. General soil assessment principles

4.1 Overview

This soils assessment methodology does not relate to any potential contaminated land. The assessment of GQAL is to be undertaken in accordance with these principles, however, the interpretation of the collected information will need to be done in accordance with that detailed in section 1.

The overall aim of the soil survey is to achieve a mapping scale of 1:50,000 to 1:100,000 scale for the rail corridor component, which is estimated at being up to a maximum distribution of one site per 1,000 m, and a minimum of one site per 500 m, as determined by *Draft for Discussion, Soil Survey for Linear Features* (DERM 2011).This largely depends on the complexity of the landscapes, which is best represented in the form of a free survey.

Free surveys are conventional in Australia and account for landscape complexity, whereby sampling locations are selected when in the field to represent differentiation in landscape attributes, ground observations and vegetation. Such a methodology facilitates aggregation of similar soil types and landscapes into soil units or unique mapping areas, which can be mapped accordingly and allows identification and segregation of problematic soils. Development of management plans such as topsoil and media suitability, soils, rehabilitation and irrigation can then be presented to minimise environmental impacts during construction works associated with the Project (Rail).

The objective of the field survey will be to ensure that every Unique Mapping Area (UMA) identified in the resultant mapping has at least one associated detailed site description. A brief description of the kinds of ground observation types and approximate proportion of these sites is provided in Table 4.

Table 4 Different ground observation types for linear soil survey

Ground observation types	Approximate proportion of sites
1. Full morphological description with full analysis Detailed descriptions of one or more representative profile soil types (more for major soils) with full profile laboratory analysis to 1.5 m, rock or trench depth.	~5 – 10%
2. Full morphological description with diagnostic analysis Detailed profile descriptions to 1.5 m or rock, or to proposed trench or excavation depth for pipelines or channels if depth >1.5 m; adequate subsoil chemical analysis (diagnostic sampling) to identify and classify the soils.	~20 – 50%
3. Brief morphological observation Less detailed soil descriptions with cores to sufficient depth to identify the soil; minimum description and recording.	~20 – 50%
4. Brief surface observation Surface features check sites in large uniform areas and to establish soil boundaries. Check sites should have a minimum of data recorded to confirm the mapped soil type, such as location, landform, vegetation, surface characteristics, surface horizon characteristics, relevant notes, and soil type.	~20 – 50%
Adapted from Forster 2011	

The breakdown above is to be adapted depending on the complexity of the landscape. Generally, full morphological descriptions are necessary as the landscape becomes more complex. Within larger and more uniform areas (alluvial plains) the assessment can be less intrusive and more confirmatory to compliment the morphological and laboratory analysis.

4.2 Data collection

Data will be collected from ground observation sites and will be referenced to the *Australian Soil Survey and Land Survey Field Handbook* (NCTS, 2009). At all sites this data will include; but not be limited to:

- Geo-location and aspect
- Land use management practices
- Landscape attributes (landform, vegetation type, land degradation, erosion, scalds; etc.)
- Micro-relief
- Full morphological description or correlate to existing mapping with sites within the survey
- Photographs of the terrain (North, South, East and West), ground surface with scale (tape measure), soil profile and any items of interest that will enable cross reference to other sites (rock outcrops, vegetation type)

4.3 Full morphological descriptions

Full morphological descriptions will include the collection and recording of the following details:

- Horizon depths
- Horizon designation
- Boundary distinctness
- Field texture
- Colour (Munsell colour chart)
- Mottles
- Coarse fragments
- Structure
- Segregations
- Field tests (e.g. pH)

4.4 Laboratory analysis

Laboratory analysis will be required to be undertaken by a National Association of Testing Authorities (NATA) or Australian Soil and Plant Analysis Council (ASPAC) accredited laboratory. Different analytical suites will be adopted based on site description. The analytical suites for the full morphological description with full analysis; and full morphological description with diagnostic analysis sites are included below.

Full morphological description with full analysis

- pH, electrical conductivity, chloride (1:5 soil water ratio)
- Exchangeable cations, cation exchange capacity, and exchangeable sodium percentage:
  - If pH is equal to or greater than 7.0 the alcoholic cations method for exchangeable cations will be used
  - If pH is less than 7.0, the aqueous cations method for exchangeable cations, will be used, and the sodium value adjusted for soluble sodium
- If pH less than 5.5 (i.e. strongly acid soils), exchangeable acidity, exchangeable aluminium and diethylenetriaminepentaacetic acid (DTPA) iron and manganese will be analysed
- Particle size analysis (hydrometer)
- Fertility suite (macro and micronutrients) – topsoil only
- Organic carbon, total nitrogen, available P – topsoil only

Full morphological description with diagnostic analysis

Adequate subsoil chemical analysis (diagnostic sampling) will be undertaken to identify and classify the soils. This will include, but not be limited to:

- pH, electrical conductivity, chloride (1:5 soil water ratio)
- Exchangeable cations, cation exchange capacity, and exchangeable sodium percentage

4.5 Sample collection protocol

Standard sample depths will be 0.0-0.1, 0.2-0.3, 0.5-0.6, 0.8-0.9, 1.1-1.2, 1.4-1.5, 1.7-1.8 m particularly for uniform or gradational soils. However, these depths will be modified to ensure that significant horizon boundaries are not crossed in the sample e.g. an A2/B1 boundary.

In collecting samples the following practices will be adopted:

- Samples will not span significant horizon boundaries
- Samples will not be bulked between sites
- No sample interval will exceed 0.3 m
- Samples will be from a detailed profile description site

Sample integrity is an important aspect of delivering a reliable soil survey, whilst the Quality Control (QC) standards are perhaps less stringent than that of contaminated land assessments, there are important considerations that will need to be adhered to which are detailed in McKenzie et al. (2008). Some of the key protocols for sampling are detailed below:

- Samples for chemical analysis will be placed into zip locked bags or pre-treated glass jars and placed into a cooler.
- Approximately 1 kilogram (kg) of soil per sample will be required to adequately analyse samples (particularly for particle size analysis) and to ensure some extra sample is retained for any future testing requirements.

- Soils are to be placed in a cooler, with a chain of custody (CoC) filled out with details of the samples collected (site identifier, date, sampler, sample code and depth) and required testing requirements.

The stipulated guidelines in McKenzie et al. (2008) will be required to be adhered to when sampling.

4.6 Sampling method

Soil sampling locations and sample methods will need to minimise surface disturbance and avoid any interaction with cultural heritage items. Approvals in relation to native vegetation clearing will need to be obtained prior to the investigation occurring should test pits be used.

Numerous sampling methodologies are available to view the soil profile; however, only some of these methodologies can be used to obtain a comprehensive understanding of the soil profile. Preference of sampling methodology is presented in Table 5. It should be noted that although preferences exist, each of the identified techniques are acceptable soil profiling techniques.

Table 5 Sampling method preference

Method	Advantage	Disadvantage	Comment
Freshly dug pit	Vertical and lateral variation is easily observed Compaction is avoided Horizons are easy to sample with little or no contamination of collected soils Exposures are easy to photograph	Pits can be costly Vegetation clearing may be required Access may be restricted and slow	To be used for full morphological description and sampling where possible, and will be best done in conjunction with any planned geotechnical investigations so as to limit the disturbance areas.
Undisturbed soil core	Quick and easy for sampling Large number of profiles can be samples Little contamination	Lateral variation cannot be easily observed Some aspects of soil structure cannot be observed Restricted access for vehicles Inadequate soil samples (in some cases may require a number of cores for one location) Refusal on coarse fragments and hard segregations	To be used for full morphological description and sampling
Existing vertical exposures – road cuttings, gully banks, borrow pits)	Accessible to depths greater than soil core Displays lateral variation over one or more landform elements May reveal stratigraphic relationships	Soil properties change because of exposure to elements Surface layers are often disturbed (scalped) Possible unstable for sampling	Best used for morphological descriptions to compliment the soil pits, cores and hand augers. Sample collection is not recommended

Method	Advantage	Disadvantage	Comment
Hand auger	Quick and efficient (depending on soil type) Steep slopes and access are not a problem Minimal requirements for equipment	Labour intensive and time consuming in deep or strong soils Undisturbed specimens cannot be collected Lateral variation cannot be observed Soil structure cannot be described readily Coarse fragments, hard segregations, sands, and hard or wet soils can cause problems	Best used to compliment the above in areas where access is difficult, particularly as confirmatory boreholes for soil boundaries

Generally, soil profile descriptions will be described to depths of 1.2 –1.8 m or until refusal is encountered. At hill slope sites soils will be described to bedrock (C or R horizon) where soil depths are less than 1.8 m. The extent of any excavations associated with the study area will be required to be considered when establishing soil depth; however in order to verify GQAL status, and soil type / limitations, target depth will still need to be 1.8 m unless a reasonable justification is approved by a suitable qualified person (CPSS (Level 2)).

5. Good quality agricultural land

5.1 Overview

The Queensland Government recognises the importance of land that is capable of sustaining long-term agricultural practices for present and future agricultural commodities. Therefore, it is required that the location and extent of GQAL be identified and included in strategic plans, where present. The protection of GQAL is defined in the State Planning Policy 1/92.

GQAL is defined as agricultural class A and class B land, and in some areas, such as the Isaac Regional Council's area, includes better quality class C (C1) land where pastoral industries predominate (DPI/DHLGP 1993). GQAL is land that is capable of sustainable use for agriculture with a reasonable level of inputs and without causing degradation of land or other natural resources in the long term. There are four agricultural land classes (A to D) defined for Queensland.

The methodology outlined in Section 1 is to be implemented for areas of GQAL, however it is to be done at a scale of 1:50,000 and evaluated and reported according to the below assessment method.

5.2 Evaluation

The principles for soil descriptions outlined in Section 1 also relate to undertaking a GQAL assessment. To determine the presence of GQAL within the study area, the land suitability of each land unit for broad acre cropping and beef cattle grazing is evaluated against the agricultural land classes, as described in the *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI/DHLGP 1993). The approximate correlation between land suitability for cropping (Land Resource Branch, 1990) and agricultural land classes is provided in Table 6.

Table 6 Broad acre cropping and grazing land suitability correlation to GQAL

Land suitability class	Land suitability description	Agricultural land class (ALC) description	ALC
1	Suitable land with negligible limitations	Crop Land – land that is suitable for current and potential crops with limitations to production ranging from negligible to moderate levels. Land is considered to be GQAL.	A
2	Suitable land minor limitations		
3	Suitable land with moderate limitations for most crops		
4	Marginal land, suitable for a very restricted range of crops, generally unsuitable to most crops due to severe limitations	Limited Crop Land – Land marginal for current and potential crops due to severe limitations, and suitable for pastures. Engineering and/ or agronomic improvements may be required before the land is considered suitable for cropping. Land is considered to be GQAL.	B

Land suitability class	Land suitability description	Agricultural land class (ALC) description	ALC
4	Marginal land, suitable for pasture only	Pasture Land – Land that is only suitable for improved pastures (C1) or native pastures (C2) due to limitations which preclude continuous cultivation for crop production, but some areas may tolerate a short period of ground disturbance for pasture establishment (C1). In areas where pastoral industries are the major primary industry, land suitable for improved and high quality native pastures may be considered to be GQAL.	C
5	Unsuitable land with extreme limitations	Non-agricultural Land – Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/ or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop or poor drainage.	D

The ALC for each land unit in the study area is to be assessed using the results of land suitability for rain fed broad acre cropping and beef cattle grazing presented DME (1995). The land suitability assessment criterion for both dry land broad acre cropping and beef cattle grazing is provided in Appendix A.

6. Contaminated land

6.1 Overview

Prior to field investigation, a desktop assessment of contamination on properties within the study area will be required in addition to the preliminary assessment undertaken in the EIS. That assessment reports on information collected in a search of the Queensland Department of Environment and Heritage Protection (DEHP) Environmental Management Register (EMR) and Contaminated Land Register (CLR).

The EMR/CLR is a registers of land for which the DEHP has been notified as previously or currently being used for a notifiable activity. A notifiable activity is deemed by the DEHP to be an activity that has the potential to cause contamination. Under the *Environmental Protection Act 1994* (EP Act), landowners must inform the DEHP if their land has been or is currently being used for a notified activity.

It is likely that the EMR/CLR register does not contain all information relevant to activities that have the potential to cause contamination for the properties being intersected by the Project (Rail). Additional information will be required to be gathered for each of the properties that will be intersected by the Project (Rail), inclusive of those sites not currently listed on the EMR/CLR.

All contaminated land assessment related to this Rail (west), is to be undertaken in accordance with the following guidelines:-

- National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1)), henceforth referred to as the NEPM 2013.
- DEHP. 2012. Guideline for contaminated land professionals. Brisbane: Department of Environment and Heritage Protection, Queensland Government. October 2012.

The extent of the contaminated land investigations can vary depending on the findings and assessment undertaken at each key stage of contaminated land assessment. Any intrusive investigations to assess contaminated land will need to be done only if there is a risk of potentially contaminated land being present within any areas to be disturbed by the Rail (west). An assessment of all properties to assess the presence (if any) of potentially contaminated land will need to be undertaken.

Any additional work relating to the assessment of contaminated land will need to be undertaken by a suitably qualified person (SQP) in accordance with the Guideline for contaminated land professionals (DEHP 2012).

6.2 Additional desktop review

Consultation with affected land holders will be required to ascertain the presence of any additional notifiable activities or potentially contaminating activities in the vicinity of property areas to be disturbed by the Project (Rail) corridor footprint. Depending on the availability and reliability of information learned from this consultation, additional assessments may be required. The landholder consultation will be required to be undertaken in conjunction with further desktop assessments.

A preliminary site investigation is proposed to be undertaken which includes a review of:

- Historical aerial photographs to assess historical land usage;

- Available previous investigation reports held by Local Councils
- Available DEHP and Council review including any relevant licences held for the site
- Available services and drainage plans for the site
- Available site specific geological and hydrogeological plans/databases to ascertain underlying lithology and hydrogeology in the context of identifying the potential for contamination to impact the surrounding environment
- Dial Before You Dig (DBYD) plans to ascertain underground service location and previous filling activities
- Interviews with personnel conversant with the current and historical operation of the site and locations of site infrastructure, and
- Surrounding land uses and identification of potentially environmentally sensitive receptors and/or potential offsite contamination sources that may impact the site.

6.3 Ground truth

The ground-truthing exercise will be required to be undertaken if the preliminary site investigation of the properties identifies the likelihood of any contamination within the final rail corridor or ancillary infrastructure areas. This ground-truthing will involve a visual inspection of the following:

- Recording of site features and layout of structures
- Inspection for visual signs of potential contamination – disturbed, distressed vegetation; soil staining etc.
- Presence/location of the following – fill; stockpiled soils/material; chemicals; fuel storage; waste material; equipment/machinery relevant to potential site contamination
- Inspection for evidence of former infrastructure; previous fuel/chemical storage, evidence of spills/leaks; condition of roads and infrastructure

6.4 Sampling and analysis plan

Following the ground-truthing exercise, any intrusive investigations and sampling needs will be identified. A Sampling and Analysis Plan (SAP) will need to be developed at this point, and tailored to each property / potentially contaminated area. The SAP is to cover the following information:

- Description of proposed activity / disturbance
- Pollution sources
- Sampling and Analysis Methodology
- Quality Assurance and Quality Control Procedures
- Data Assessment and Reporting

7. Ancillary infrastructure and quarries

7.1 Overview

The soil survey for ancillary infrastructure does differ to that presented in Section 1, general soil assessment, as construction of infrastructure deviates from a linear form. However the principles with regards to the information and laboratory testing to be collected are the same.

The benefit of the information collected from these assessment are establish erosion risk of the soils to be disturbed, salvage of topsoil and growth media material for rehabilitation, GQAL status (if relevant), and to inform rehabilitation standards.

During the soil study field work the target will be to ensure every UMA that is produced in the resultant mapping, following the field work, will contain at least one detailed site description.

The ancillary infrastructure is located outside of the 95 m rail corridor, generally positioned directly adjacent to the alignment at strategic locations. These ancillary infrastructure areas are listed in Table 7 and are separated based on location in relation to the Rail (west) and Rail (east) components of the Project (Rail). Ancillary infrastructure aligning with Rail (west) was provided by Adani; however, those components associated with Rail (east) were updated according to data provided by Adani in Option 9, Revision 3.

Table 7 Ancillary Infrastructure associated with Rail (west) and Rail (east)

Ancillary Infrastructure	West	East
Bridge Laydown Area	17	8
Construction Depot	1	0
Turning Circle	26	18
Track Laydown Area	18	11
Batching Plants	5	0
Maintenance Facility	1	0
Ballast Stockpile	0	1
Construction Camp	2	1
Access Roads	0	1

There are a total of five quarries, identified as Disney, Borrow 7, Back Creek South, Moray Quarry and North Creek. Associated with these quarries are also access tracks. These have been positioned within the region to extract quarry materials for construction and operational purposes

7.2 Soil survey requirements

Free form surveys will be used to allow some flexibility in sampling extent (see Table 8). For instance, ancillary infrastructure in close proximity to the Rail corridor may be sampled as check sites if landform and soil type is undifferentiated from the full morphological sample collected from the footprint of rail infrastructure. However, detailed and analysed samples should be collected from sites positioned further from the rail infrastructure, where soil types are clearly different from that within the rail corridor.

Those principles detailed in section 1 will apply to this survey; however the soil survey and resultant mapping will be conducted at a scale of 1:10,000, which equates to 1 site per 0.8 – 4 ha.

Table 8 Ground observation types and proportions for the quarry and ancillary infrastructure surveys

Ground observation types	Approximate proportion of sites
1. Full morphological description with full analysis Detailed descriptions of one or more representative profile soil types (more for major soils) with full profile laboratory analysis to 1.5 m, rock or trench depth. Sampling is to characterise the typical / reference soils in a survey or to target selected soil attributes such as fertility sodicity or salinity.	~5%
2. Full morphological description with diagnostic analysis Detailed profile descriptions to 1.5 m or rock that can be used to characterise the main soil and landscapes in a survey area.	~10 – 30%
3. Brief morphological observation / surface observations Surface features check sites in large uniform areas and to establish soil boundaries. Check sites should have a minimum of data recorded to confirm the mapped soil type, such as location, landform, vegetation, surface characteristics, surface horizon characteristics, relevant notes, and soil type.	~60 – 88%
Source: McKenzie et al., 2008	

7.2.1 Ancillary infrastructure

For those ancillary infrastructure areas that are less than 10 ha in size, Mapping will be conducted at a scale of 1:10,000, which equates to 1 site per 0.8 – 4 ha. However it may be the case that the soils information collected within the rail corridor can be extended to include the ancillary infrastructure areas. This will be the case when confirmatory sites (check sites and brief morphological descriptions) within the ancillary infrastructure areas confirm the soil type is the same as that identified within the immediate adjacent rail corridor. It is not intended for each ancillary infrastructure area to be surveyed at a scale of 1:10,000 but for those areas where additional information is needed to compliment the information collected in the soil survey, it is to be done in order to provide detailed information that will constitute a 1:10,000 assessment.

For those areas which are above 10 ha in size, which is the ballast stockpile (28 ha) and the rail construction depot (264 ha), a broader scale survey at a scale of 1:25,000 is required to be undertaken. This equates to a site positioned 1 per 5 – 25 ha.

7.2.2 Quarries

The soil survey methodology for proposed quarries is similar to that presented for ancillary infrastructure in section 7.2.1. Sampling intensity is to be conducted on a scale of 1:25,000, which equates to 1 site per 5 ha to 25 ha. It is unlikely, due to the location of the quarries with relation to the rail corridor and ancillary infrastructure, that information collected from soil surveys in those areas will be able to be extrapolated to the 5 quarry sites. Those principles detailed in section 1 will apply to this survey.

8. Existing 1:100,000 mapping

8.1 Overview

Two publicly available land system reports and one soil survey report are relevant to the Study Area. These are as follows:

- Lorimer, M.S, 2005, The Desert Uplands: An Overview of the Strategic Land Resource Assessment Project, Technical Report. Environmental Protection Agency, Queensland Government, Brisbane.
- Gunn, R.H., Galloway, R.W., Pedley, L. and Fitzpatrick, E.A, 1967, Lands of the Nogoa - Belyando Area, Queensland - Land Research Series No. 18, Commonwealth Scientific and Industrial Research Organisation, Melbourne.
- Shields, P.G., Chamberlain H.J., and Booth N.J, 1993, Soils and Agricultural Use, in the Kilcummin Area, Central Queensland, Project Report Series: QO93011, Department of Natural Resources and Mines,

Use of the reports by Lorimer (2005) and Gunn et al. (1967) to ground truth soil types and to predetermine sites of soil investigations are of limited value due to the broad scale mapping and methodologies used in the surveying and reporting. The soils information for the below soil types are provided in Appendix B.

8.2 Existing soils information

The *Soils and Agricultural Use in the Kilcummin Area, Central Queensland* (Shields et al., 1993) describes the eastern 24 km of the study area (rail corridor and ancillary infrastructure) and is mapped at a scale of 1:100,000. Thirteen soil types have been identified within this portion of the rail corridor.

Heyford Soil Type (Sodosol)

A hard setting duplex soil with sandstone gravel and, dark to red-brown, loamy sand to sandy clay loam surface and bleached subsurface over alkaline, mottled grey-yellow and red-brown clay subsoil overlying sandstone. The soils on these areas have a drainage rating of three and a permeability rating of one. These soils tend to be located on gently undulating plains and rises and formed from Permian sedimentary rocks. The predominant vegetation associated with this group is poplar box woodland.

Cherwell Soil Type (Rudosol)

A very rocky and gravelly, red-brown to dark, sand to sandy clay loam with acid to neutral reaction trend overlying sandstone by 600 mm depth. The soil in these areas has a drainage rating of five, and a permeability rating of three. These soils are found on rolling low hills undulating rises and plateau remains, overlying Permian sedimentary rocks. The predominant natural vegetation is lancewood scrub.

Lebanon Soil Type (Sodosol)

A hard setting duplex soil with ferruginised gravel and, dark to brown, loamy sand to sandy clay loam surface, usually with a bleached subsurface, over a generally mottled grey-brown, yellow-

brown and red clay subsoil with neural to alkaline reaction trend overlying ferricrete. The soils on these areas have a drainage rating of three and a permeability rating of one.

The associated landscapes are level to gently undulating plains and have formed from Cainozoic ferricrete and weathered sediments. They tend to be associated with poplar box open woodlands.

Fletcher Soil Type (Kandosols)

A firm to hard setting, red to grey-brown, non-cracking clay with neutral to alkaline reaction trend overlying unconsolidated sediments. The soil on these areas has a drainage rating of four and a permeability rating of two. These soils tend to be located on alluvial plains, overlying Quaternary alluvium. They are often associated with poplar box or coolibah woodlands.

Kenmar melonhole Soil Type (Vertosol)

A normal linear and lattice gilgai complex overlying buried layers. The mounds are self-mulching to firm, grey to grey brown clay with acid to alkaline reaction trend. The depressions are very fine self-mulching, dark to grey-brown, cracking clay with acid to alkaline trend. These soils tend to be located on elevated, levels plains to undulating rises. They tend to form on overlying Cainozoic clay sediments and are often associated with gidgee or brigalow scrub.

Villafranca Soil Type (Kandasol)

Villafranca soil is a hard setting, red, massive, gradational soil with acid to neutral reaction trend overlying ferricrete.

8.3 Assessment methodology

Due to the already detailed nature of the existing soils information in this section of the study area, the assessment approach is to undertake a ground truthing assessment of the reported soil types. The soils information for the above soil types is provided in Appendix C

9. Reporting

9.1 Overview

Due to the range of assessments that will be undertaken relating to soils, a number of reports will be required for development and issued for each development front (see Table 9). These reports are likely to form part of the overarching CEMP.

Table 9 Reports be produced from soil surveys

Study	Master Report	Other Documents Generated or Benefited
General Soil Survey GQAL	Soils and Land Suitability Report	Soil Management Plan Rehabilitation Management Plan Erosion and Sediment Control Plan
Contaminated Land	Phase 1 Site Contamination Assessment Sampling Analysis Plan Phase 2 Site Contamination Assessment	Construction Environmental Management Plan and Operational Environmental Management Plan
Ancillary Infrastructure	Soils and Land Suitability Report	Soil Management Plan Rehabilitation Management Plan Erosion and Sediment Control Plan
Quarries	Soils and Land Suitability Report	Soil Management Plan Rehabilitation Management Plan Erosion and Sediment Control Plan

9.2 General soil survey

An overarching soils and land suitability technical report will be prepared for the Rail (west) footprint that includes descriptions of the soil landscape units, figures of the soil distributions, laboratory results, soil classifications, and landscape details, limitations and constraints, and recommendations. Land suitability of areas will be determined for cropping and grazing, as well GQAL status of these lands. This section will incorporate areas intersected by rail infrastructure, ancillary infrastructure and quarries.

A mapping exercise will be completed following the field work to develop UMAs that reflects variations in geology, landform, drainage, and vegetation along the alignment. Each delineated UMA is presumed to be unique until an explicit classification proves it to be similar or identical to another tract. A UMA is an area of land where the attribute values are sufficiently uniform and distinct from neighbouring areas to justify its delineation. UMAs will be characterised based on their attributes to determine land suitability. These will be classified in regard to:

- Land suitability for cropping and grazing
- GQAL status

Soil types will be grouped by parent material and position in the landscape with examples provided below. These will be similar categories that will be detailed in the Soil Management Plan along with key management procedures required:

- Shallow, stony loamy soil
- Shallow cracking clay
- Deep cracking clay
- Deep saline and/or sodic cracking clay
- Deep saline and/or sodic cracking clay with melon holes
- Shallow non-cracking clay
- Deep non-cracking clay
- Deep saline and/or sodic non-cracking clay
- Loamy surface, non-sodic duplex soil
- Thin surface, sodic duplex soil
- Medium to thick surface (>15 cm), sodic duplex soil
- Massive gradational textured soil

All maps will followed cartographic conventions, and will include the following:

- Scale for polygonal data, cell size and scale for rasters
- North arrow
- MGA grid
- Appropriate locality data e.g. towns, administrative boundaries
- Legend
- Due reference to data sources and currency of data
- Date of preparation
- Statement of any limitations of the data/map e.g. related to scale, accuracy, reliability
- Location of soil profile descriptions and sampling sites must always be provided on a suitable map e.g. soil/landscape map

9.3 Good quality agricultural land

A report will be prepared following field investigation to validate the land suitability of each land unit triggered as GQAL for broad acre cropping and beef cattle grazing. Laboratory results, bore logs, soil classifications, limitations and constraints, figures and maps will be produced to support conclusions. The report will be developed in accordance with *Planning Guidelines: The Identification of Good Quality Agricultural Land* (DPI/DHLGP 1993) and GQAL status assigned as Class A, B, C1, C2 or D.

9.4 Contaminated land

Where intrusive investigations are required, a detailed site investigation report will be prepared. Following this, information from the preliminary and detailed site investigation reports will be used to support the validation of the CEMP. Amongst other environmental factors, the CEMP will detail the legislative requirements, contamination status of areas being disturbed by the Project (Rail) project, potential impacts and mitigation and management measures, procedures and actions.

9.5 Ancillary infrastructure

Reporting within this category will be incorporated into the General Soils Report, detailed in Section 9.2.

9.6 Quarries

Reporting within this category will be incorporated into the General Soils Report, detailed in Section 9.2.

9.7 Existing 1:100,000 mapping

Reporting within this category will be incorporated into the General Soils Report, detailed in Section 9.2.

10. Summary

As part of the Carmichael Coal Mine and Rail EIS Terms of Reference, a soil survey is required to be undertaken of the impacted areas associated with the development of the Project. This soil survey methodology provides a detailed framework from which an assessment of soil related values can be undertaken. The soil survey methodology relates to all aspects of the Project (Rail), inclusive of the rail corridor (east and west), quarries and ancillary infrastructure.

The soil survey has been divided into six broad categories of assessment which have been deemed as necessary to assess. Each of the six soil assessment related methodologies details principles justifying the need for conducting surveys, mapping scale, intensity of ground observations, sample methodology and reporting requirements.

The general soil assessment survey for the rail corridor is to be conducted based on a linear survey technique at a scale of 1:50,000 to 1:100,000 (1 site per 500 – 1,000 m) depending on the complexity of the terrain. When assessing the ancillary infrastructure an 'area' scale survey will be implanted whereby a scale of 1:10,000 (1 site per 0.8 – 4 ha) to 1:25,000 (1 site per 5 – 25 ha) is to be adopted. The assessment of quarries is to be undertaken at a scale of 1:25,000. Areas of GQAL will need to be assessed based on a scale of 1:50,000. Soil sampling on areas previously mapped at a scale of 1:100,000 will be validated at a scale of 1:100,000.

A free survey is suggested as the preferred option to conduct all the soil surveys with the exception of the contaminated land assessment. This assessment will identify soil types and Unique Mapping Areas based on the sampling intensity to be adopted.

Areas of potential contaminated land must first be identified through a desktop assessment and ground truthing exercise. Any intrusive investigation requirements for contaminated land will be established in light of this desktop and ground-truthing information.

Key deliverables have been identified for submission to the Proponent in advance of milestones. Reports will be issued progressively throughout the four stages of development with relevant information provided to the four working Fronts. Master reports following field investigations have been identified below, and will form the basis for generation of subsequent reports regarding issues such as soil management plans, construction environmental management and contaminated land management:

- Soils and land suitability report (including general soil survey, GQAL, contaminated land, ancillary infrastructure, quarries, existing 1:100,000 mapping)
- Phase 1: site contamination assessment
- Sampling analysis plan (for contaminated land, if required)
- Phase 2: site contamination assessment (if required).

It is intended that this soil survey methodology be implemented during the enabling works periods, prior to the earthworks commencing. This soil survey methodology is adaptive to future changes in design and disturbance areas.

11. References

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Appendices

Appendix A – Land Suitability Assessment

Land Suitability Assessment – Land Qualities

Land Qualities used in the assessment are based on the Land Suitability Assessment Techniques (DME 1995); Guidelines for Agricultural Land Evaluation in Queensland (DPI 1990), and Land evaluation standards for land resource mapping (DoA 2005).

Water availability

Plant yield will be limited by periods of water stress. The SWS capacity is influenced by surface condition, texture, structure, soil depth and other impediments to water entry and water retention in the soil. Soils with very low water storage are likely to limit crop yields in most seasons, whilst those with low water storage are likely to limit yields in low rainfall seasons or where distribution of the rainfall is irregular. Poor ground cover associated with low yields increases the risk of wind and water erosion as well as contributing to recharge, leading to the development of salinity.

On soils with very low water storage, pastures are less productive. Poor groundcover increases the risk of wind and water erosion as well as contributing to recharge leading to the development of salinity at the lower portions of the landscape.

Nutrient deficiency

Plants require adequate levels of various nutrients to maintain growth. Inadequate nutrient supply may cause reductions in plant yield, particularly during critical periods such as flowering or fruiting. Livestock production may be limited by either reduction in pasture growth or nutritive value caused by low soil nutrients. The levels of available phosphorus and potassium in the topsoil are the main criteria used to evaluate nutrient deficiency of the soil.

The addition of fertilisers is an accepted practice for many land uses where inherent fertility between soil types is not considered important enough to downgrade suitability. However nutrient deficiency may be used to downgrade suitability where returns may be too low or unreliable to justify the application of fertilisers in more extensive land uses such as grazing or rainfed broadacre cropping in marginal areas.

Soil physical factors

Clays with coarse surface aggregates and soils with hardsetting surface affect germination and seedling development. Additional efforts are required to manage these soils.

Soil workability

Stiff cracking clays with coarse surface aggregates and hardsetting surface soils are difficult to work into a favourable tilth. Clayey surface soils have the additional difficulty of a narrow moisture range where machinery can be operated on.

Salinity

Soil salinity can affect crop growth by reducing the water available to the crop (osmotic effect) and by increasing the concentration of certain ions that have a toxic effect on plant metabolism (specific effect) (FAO 1985). Where the soil rooting depth is not limited by a physical barrier, for example, weathered rocks, it can be restricted by the presence of high salinity within the soil profile. Whilst crop tolerance to salinity varies it is the combination of salinity and waterlogging that

has the greatest impact on crops. Management of affected areas can include increasing plant water use in recharge areas, improving site drainage and establishment of salt tolerant pastures.

Rockiness

Stony or rocky soils influence soil properties such as infiltration, erosivity, susceptibility to compaction, and soil water storage, as well as causing impedance to cultivation and damage to machinery. Surface scree, large stones or outcrops limit production by reducing the surface area and volume of soil available for plant growth and may lead to difficulties in mustering livestock and fencing.

Microrelief

The presence of gilgai, small gullies, or small differences in topography will increase the amount of levelling and earthworks for cultivation. Melonholes > 60cm deep over 50 % of the area can be a serious limitation and result in the land unsuitable to cultivation.

pH (grazing)

Extremes of pH affect the availability of nutrients resulting in deficiencies and/ or toxicities that adversely affect production. Management options are limited to growing tolerant crops or the use of lime and other ameliorants to increase or adjust the pH of soils.

In pasture highly acidic soils reduce production of most legume species. Management options include growing tolerant species and using acid-tolerant Rhizobia and/or applications of lime. Medics can be selected for highly alkaline soils.

Exchangeable sodium percentage of the upper 0.1m (Grazing)

A soil is considered sodic when sodium reaches a concentration where it starts to affect soil structure, which in Australian soils is commonly at an ESP > 6 % (Isbell, *et al* 1983). Northcote and Skene (1972) defined sodic soils as having an ESP of 6 to 14 % and strongly sodic soils with ESP of > 14 %. A soil with high levels of sodium is liable to dispersion of particles causing deterioration of the soil physical condition. The effects of physical deterioration of the soil are waterlogging, crusting and hardsetting, poor infiltration, reduction of plant available water, poor seedling emergence, poor aeration and poor root development. These adverse properties are clearly manifested in soils with ESP > 14 %. The depth at which an ESP > 14 % occurs in the soil profile has been taken as the rooting depth in calculating plant available water or soil water status.

Wetness

Waterlogging reduces crop yields especially if it occurs early in crop development or when the temperatures are higher in spring. It can delay effective machinery operations. Management options include cropping on raised beds, improved site drainage and/ or growing tolerant crops.

Waterlogging can limit pasture production with varying degrees of severity. The effects of waterlogging are often far from obvious. Mildly waterlogged pastures can look healthy but have significant yield reductions. Management options include the uses of waterlogging tolerant pasture species and the construction of surface drains.

Topography

Slopes > 20 % are regarded as unsafe for machinery use and therefore regarded as unsuitable for cropping. The presence of many gullies may result in discontinuities and make cultivation and sowing of pastures impracticable, whilst greatly dissected terrain (that is > 75 % of the area) may prevent adequate herd management.

Water erosion

Water erosion can reduce crop yields, result in the loss of nutrients and reduce productive potential. As a general rule, the risk of water erosion is likely to become limiting on slopes with gradients in excess of 10 %. Management options include the adoption of no-till systems, sowing on the contour and installing banks to control the length of slope and/or reduce waterlogging.

Water and wind erosion generally lead to a slow decline in productivity, though extreme events can have a more immediate impact. Management can include excluding stock from highly susceptible areas, maintaining ground cover through control of stocking rates, the construction of earthworks to control runoff and the establishment of windbreaks.

Flooding

Floods can damage crops greatly reducing the yield. Areas prone to flooding also have a higher risk of water erosion. For grazing land uses flood hazard is only severe if flooding would affect pasture production or endanger stock.

Vegetation regrowth (grazing)

After clearing, some native species will rapidly re-establish to a density greater than before. Where cultivation and cropping is practiced this regrowth is controlled; however in some extensive grazing land uses the cost of timber clearing and regrowth is considered significant.

Land suitability criteria are summarised on the following pages.

Land suitability criteria for rain fed broad acre cropping

Limitation	Class 1	Class 2	Class 3	Class 4	Class 5
Water availability	>150mm	125-150mm	100-125mm	75-100mm	> 75mm
Nutrient deficiency	Bicarbonate P > 10 parts per million (ppm)	Bicarb. P 5-10ppm and exchangeable K > 0.3 milliequivalents per 100 grams (meq/100g)	Bicarb. P 5-10ppm and exchang. K > 0.3meq/100g Or pH > 5 0.6-0.9m bgl Or pH > 9 0.6-0.9m bgl	Bicarb. > 10ppm and exchang. K > 0.3meq/100g and exchang. Ca > 3meq/100g Or pH > 5 0.6-0.9m bgl Or pH > 9 0.6-0.9m bgl	pH > 5 0.6-0.9m bgl Or pH > 9 0.6-0.9m bgl
Soil physical factors	Cracking clays with very fine self-mulch (peds < 2mm) Or Rigid soils with a loose, soft or firm surface when dry	Cracking clays with fine self-mulch (peds 2-10mm)	Cracking clays with coarse self-mulch (peds 10-20mm) Or Rigid soils with a hard setting surface when dry	Cracking clays with coarse peds at the surface (≥l to 20mm)	
Soil workability	Friable cracking clays (indicated by very fine self-mulch) Or Rigid soils with a loose, soft or firm surface when dry	Firm cracking clays (indicated by fine self-mulch) Or Rigid soils with a hard setting surface when dry	Stiff cracking clays (indicated by coarse self-mulch with peds > 10mm, crusting or hard setting surface)		
Salinity	Root zone EC < 0.15mS/cm Or Root zone Cl < 300ppm	Root zone EC 0.15-0.3mS/cm Or Root zone Cl 300-600ppm	Root zone EC 0.3-0.9mS/cm Or Root zone Cl 600-900ppm	Root zone EC 0.9-1.2 mS/cm Or Root zone Cl 900-1500ppm	Root zone EC > 1.2mS/cm Or Root zone Cl ≥ 1500ppm
Rockiness	< 10 % coarse surface gravel (> 60mm) and rock outcrop	10-20 % coarse surface grave and rock outcrop	20-50 % surface cobble (60-200mm) and rock outcrop	50-90 % surface cobble and rock outcrop Or 20-50 % stone and boulders (> 200mm)	> 90 % surface bobble and rock out crop Or > 50 % stone and boulders and rock outcrop
Microrelief	No melonholes (semi-circular depressions < 300mm deep and usually surrounded by mounds)	Melonholes 300-600mm deep and cover < 20 % surface area Or Melonholes > 600mm deep and cover < 10 % surface area	Melonholes 300-600mm deep and cover 20-50 % of surface area Or Melonholes > 600mm deep and cover 10-20 % surface area	Melonholes 600-1000mm deep and cover 50 % of surface area	Melonholes 1000mm deep and cover 50 % of surface area

Limitation	Class 1	Class 2	Class 3	Class 4	Class 5
Wetness	Undulating terrain or elevated plains	Low-lying level plains with melonholes covering < 25 % surface area	Low-lying level plains with melonholes covering 25-50 % surface area	Seasonal swamps and low-lying run-on areas	Permanent swamps and lakes
Topography	No gully dissection	Occasionally deep gullies impede cultivation slightly	Many deep gullies reduce arable area by < 33 % or require major changes to cultivation practices	Many deep gullies make the arable areas too small to cultivate	Abundant deep gullies prevent any practical cultivation
Water erosion	Slopes less 0.5 % (clays without melonholes) or slopes < 1 % on melonhole clays	Slopes 0.5-1 % (clays without melonholes) or slopes 1-3 % on melonhole clays	Slopes 1-3 % (clays without melonholes)	Slopes 3-5 %	Slopes greatre than 5 %
Flooding	No flooding	Rare flooding (only during abnormal 1 in 50 to 100 year events)	Infrequent flooding (inundation occurs < half the times that stream flow increases)	Occasional flooding (inundation occurs ≥ half the times that stream flow increases)	Regular flooding (inundation occurs whenever stream flow increases)

P = phosphorus, K = potassium, Ca = calcium, Cl = chlorine

Land suitability criteria for beef cattle grazing

Limitation	Class 1	Class 2	Class 3	Class 4	Class 5
Water availability	> 125mm	100-125mm	75-100mm	50-75mm	≤50 mm
Nutrient deficiency	Brigalow, gidgee, blackwood or softwood scrub soils and former scrub soils with bicarb. P > 10ppm	Eucalypt vegetation and downs with bicarb. P > 10ppm	Other soils with bicarb. P 5-10ppm	-	-
Soil physical factors	Cracking clays with very fine self-mulch (peds > 2 mm)	Cracking clays with fine self-mulch (peds 2-10 mm)	Cracking clays with coarse self-mulch (peds 10-20 mm)	-	-
Salinity	Root zone EC < 0.15 mS/cm Or Root zone Cl les than 300 ppm	Root zone EC 0.15-0.3 mS/cm Or Root zone Cl 300-600ppm	Root zone EC 0.3-0.9mS/cm Or Root zone Cl 600-900ppm	Root zone EC 0.9-1.2 mS/cm Or Root zone Cl 900-1500ppm	Root zone EC >1.2 mS/cm Or Root zone Cl ≥1500 ppm
Rockiness	< 20 5 coarse surface gravel (> 60 mm) and rock outcrop	20-50 % coarse surface gravel and rock outcrop	50-90 % surface cobble and rock outcrop	> 90 % surface cobble and rock outcrop	Rock outcrop and surface coarse fragments cover total area
Microrelief	Melonholes (> 300mm deep) cover < 20 % surface area	Shallow melonholes (300-600mm deep) cover 20-50 % surface area	Deep melonholes (> 600mm deep) cover 20-50 % surface area	-	-
pH (1:5)	5.6-6.6	6.6-8.0; 5.0-5.6	8.0-9.0; 4.5-5.0	9.0-10.0; 4.0-4.5	>10.0; >4.0
ESP (topsoil)	< 5.0	5-10	10-15	15-30	>30
Wetness	Undulating terrain or elevated plains	Low-lying plains	Shallow seasonal and permanent swamps	-	Permanent lakes and deep swamps
Topography	-	-	-	Many deep gullies make cultivation for sowing pastures impractical Or slope > 15 % make cultivation along contours impractical	Strongly dissected terrain over ≥75 % of the area preventing adequate herd management

Limitation	Class 1	Class 2	Class 3	Class 4	Class 5
Water erosion	Slopes < 1 % on sodic rigid soils Or Slopes < 3 % on all other soils	Slopes 1-3 % on sodic rigid soils Or Slopes 3-12 % on non-sodic rigid soils Or Slopes 3-6 % on cracking clays	Slopes 3-6 % on sodic rigid soils Or Slopes 12-20 % on non-sodic rigid soils Or Slopes 6-9 % on cracking clays	Slopes 6-12 % on sodic rigid soils Or Slopes 20-45 % on non-sodic rigid soils Or Slopes 9-15 % on cracking clays	Slopes >45 %
Flooding	No flooding	Periodic flooding (from once in 50 years to whenever stream flow increases)	-	-	-
Vegetation regrowth	Softwood, brigalow, gidgee or blackwood scrub without melonholes or QLD bluegrass grasslands or mountain coolabah, bloodwood and ironbark open woodlands	Brigalow, gidgee or blackwood scrub with melonholes or ironbark woodlands without wattle understory or coolabah woodlands on flooded country	-	Eucalypt woodlands with wattle understorey or broad-leaved tea tree woodlands	-

Appendix B – Soils information from 1:100,000 mapping

Heyford Soil Type

Major attributes: A duplex soil with sandstone gravel and hard setting, dark to red-brown, loamy sand to sandy clay loam surface and bleached subsurface over an alkaline, mottled grey, yellow and red-brown clay subsoil overlying sandstone

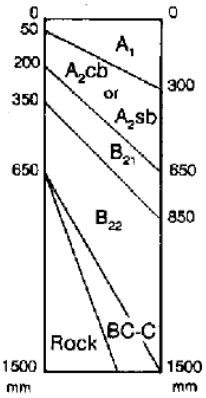
Principal profile forms: Dy3.43, Dy3.33 **Great soil group:** Solodized solonetz and solodic soil

Parent material: Permian (and minor Devonian-Carboniferous) sedimentary rocks

Landform: Gently undulating plains and rises

Predominant vegetation: Poplar box, tall, open woodland to woodland

Surface features: May have common, fine to medium gravel; hard setting



A_1: Dark to red-brown (5YR to 10YR 3/2 to 4/4), grey-brown to brown (dry); loamy sand to sandy clay loam, massive; dry very weak to moderately weak; may have common fine to medium quartz and sandstone gravel; pH 6.0-7.5. Abrupt to gradual to -

A_2cb or A_2sb: Red-brown to grey (5YR to 10YR 4/3 to 6/4); loamy sand to light sandy clay loam; massive; dry very weak to moderately weak; may have very abundant coarse quartz and sandstone gravel; pH 5.5-7.5. Abrupt to clear to -

B_{21}: Mottled grey, yellow and red-brown (10YR to 5YR 4/1 to 6/2 and 5/4 to 6/8); sandy, medium clay to medium heavy clay; medium to strong >100 mm columnar, prismatic or angular blocky; dry very firm to very strong; may have common fine to coarse gravel; may have few soft manganiferous segregations; pH 6.0-8.0. Clear to gradual to -

B_{22}: As for B_{21}, except may have common carbonate soft segregations and nodules; pH 8.5-9.0. Clear to gradual to -

BC-C (where present): Grey to yellow-brown (7.5YR to 10YR 5/2 to 6/6); sandy, light medium to medium clay; may have common grey and yellow mottles; may have very abundant sandstone gravel; may have common carbonate soft segregations and nodules; pH 8.5-9.0

Notes: 1. Occasionally, the B_{21} is strongly alkaline; a bleach may occur in the A_1; rarely, an acid profile (Dy3.41) may be encountered.

2. Occasionally, red-brown profiles without a bleached A_2 (Db1.23, Dr2.12) are encountered.

Cherwell Soil Type

Major attributes: A very rocky and gravelly, red-brown to dark, sand to sandy clay loam with acid to neutral reaction trend overlying sandstone by 600 mm depth

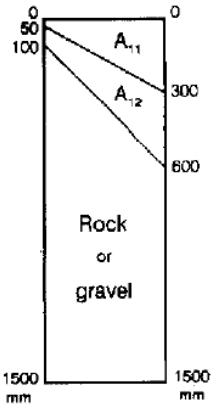
Principal profile forms: Uc1.23, Uc1.21, Um1.23, Uc1.24 **Great soil group:** Lithosol

Parent material: Permian quartzose sandstone

Landform: Rolling low hills to undulating rises

Predominant vegetation: Lancewood, mid-high to tall, open to closed forest

Surface features: May have 50% rock outcrop and few to abundant, fine quartz gravel and sandstone cobble; soft to hard setting



A_{11}: Red-brown to dark (5YR to 10YR 4/4 to 2/2), brown to light grey (dry); loamy coarse sand to sandy clay loam; massive; dry very weak to moderately weak; may have abundant fine to medium, quartz and sandstone gravel; pH 5.0-7.0. Clear to gradual to -

A_{12} (where present): Brown to red-brown (5YR to 7.5YR 3/3 to 5/4); coarse sand to sandy clay loam; apedal; dry loose to moderately weak; may have abundant fine to coarse quartz and sandstone gravel; pH 5.0-6.5.

Note: Occasionally, a conspicuously bleached A_2 may occur, instead of the A_{12}, over a thin C horizon overlying rock (Uc2.12).

Lebanon Soil Type

Major attributes: A duplex soil with ferruginised gravel and hard setting, dark to brown, loamy sand to sandy clay loam surface, usually with a bleached subsurface, over a generally mottled grey-brown, yellow-brown and red clay subsoil with neutral to alkaline reaction trend overlying ferricrete

Principal profile forms: Dy3.33, Dy3.32, Dy3.43, Dy3.42, Dy2.43, Dy2.12

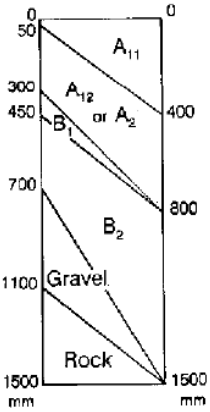
Great soil group: Solodized solonetz and solodic soil, and no suitable group (affinities with solodized solonetz and solodic soil)

Parent material: Cainozoic ferruginised sediments (soil material and gravel)

Landform: Level to gently undulating plains

Predominant vegetation: Poplar box, tall, open woodland to woodland

Surface features: May have common, fine to medium, ferruginised gravel; hard setting



A_{11}: Dark to brown and red (7.5YR to 5YR 3/2, 4/2 to 5/4); grey to brown (dry); loamy sand to sandy clay loam; massive; dry very weak to moderately firm; may have common fine ferruginised gravel; pH 5.8-8.0. Abrupt to gradual to -

A_{12} or A_2: Grey-brown to red (7.5YR to 5YR 4/4 to 6/6), brown to light grey (dry); sand to sandy clay loam; massive; sporadically or conspicuously bleached; dry loose to moderately firm; may have abundant fine to medium ferruginised gravel; pH 5.8-8.0. Abrupt to clear to -

B_1 (where present): Generally mottled grey-brown, yellow-brown and red (5YR to 10YR 6/2 to 6/6); clay loam, sandy to light medium clay; may be sporadically bleached; dry moderately firm to very firm; may have many fine to medium ferruginised gravel; pH 6.0-7.0. Abrupt to gradual to -

B_2: Generally mottled yellow-brown, grey and brown to red (5YR to 10YR 4/6 to 6/8 and 5/2 to 7/2); light medium to medium heavy clay; dry very firm to very strong; may have many fine to medium, ferruginised gravel; may have common manganiferous nodules and veins and few carbonate nodules and soft segregations; pH 7.0-8.7

Notes:

1. The B_2 horizon overlies either ferricrete (rounded ferruginised gravel cemented together by iron oxides) or, occasionally, ferruginised sandstone.
2. The whole coloured profiles (Dy2) have yellow-brown to brown B_2 horizons with few grey mottles.

Fletcher Soil Type

Major attributes: A firm to hard setting, red to grey-brown, non-cracking clay with neutral to alkaline reaction trend overlying unconsolidated sediments

Principal profile forms: Uf6.31, Uf6.33

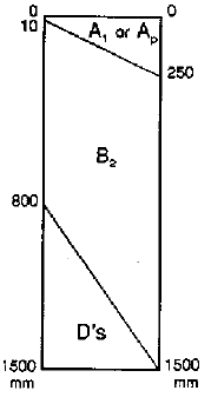
Great soil group: No suitable group

Parent material: Quaternary alluvium

Landform: Alluvial plains (may be frequently flooded)

Predominant vegetation: Poplar box or coolibah, tall, open woodland to woodland

Surface features: May have abundant, fine to coarse, quartz, basalt and other gravel; firm to hard setting



A_1 or A_p: Grey-brown to red and occasional dark (7.5YR to 2.5YR 4/2, 4/3, 3/3, 3/4 and occasional 3/2), grey-brown to red (dry); sandy clay to sandy, medium heavy clay; massive to moderate 2-5 mm subangular blocky; dry moderately weak to moderately strong; may have common fine to medium quartz, basalt and other gravel; pH 6.0-8.5. Abrupt to gradual to -

B_2: Red to grey-brown (2.5YR to 10YR 5/6 to 3/3, and 4/2); medium to heavy clay; may have 50% grey and yellow mottles at depth; dry very firm to moderately strong; may have many fine to medium quartz, basalt and other gravel; may have common carbonate nodules and soft segregations and common manganiferous nodules and soft segregations and common gypsum crystals; pH 6.0-8.7. Clear to gradual to -

D's: Gravel, gravelly clay and sand or strongly and coarsely mottled, acid, gleyed clay

Note: Structure in the B_2 horizon of some profiles may be only weakly pedal (Uf6.53).

Kenmar melonhole Soil Type

Major attributes: A normal, linear and lattice gilgai complex overlying buried layers
Mounds: self-mulching to firm, grey to grey-brown clay with acid to alkaline reaction trend
Depressions: very fine self-mulching, dark to grey-brown, cracking clay with acid to alkaline reaction trend

Principal profile forms: *(mounds):* Uf6.33, Ug5.25, Ug5.24 **Great soil group:** *(mounds):* No suitable group and grey clay
(depressions): Ug5.24, Ug5.15, Ug5.25 *(depressions):* Grey clay and black earth

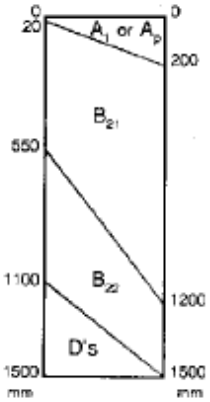
Parent material: Cainozoic unconsolidated sediments

Landform: Level to gently undulating plains

Predominant vegetation: Gidgee and brigalow, tall to mid-high, open forest to woodland

Surface features: Normal, linear and lattice gilgai (vertical interval .05-.25 m, horizontal interval 5-30 m); may have many, fine to coarse, quartz and ironstained gravel; self-mulching to firm (occasionally hard setting) on mounds, cracking and self-mulching in depressions

Mounds



A_1 or A_p: Dark to grey and occasional brown (10YR to 7.5YR 3/2 to 5/2 and occasional 3/3, 4/3), grey to grey-brown (dry); light medium to medium heavy clay; weak to moderate 2-10 mm subangular blocky frequently parting to strong <2 mm subangular blocky and granular; dry very firm to loose; may have common fine to medium quartz and ironstained gravel; may have many carbonate nodules; pH 7.0-9.0. Clear to gradual to -

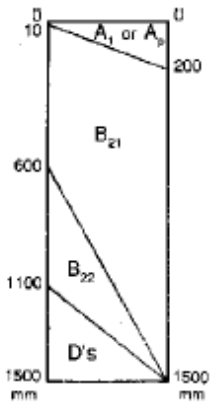
B_{21}: Grey, dark or grey-brown (2.5Y to 7.5YR 3/1 to 6/2); medium to heavy clay; moderate 10-50 mm blocky becoming lenticular with depth; dry very firm to very strong; may have few fine to coarse quartz and ironstained gravel; may have many carbonate nodules and soft segregations, common gypsum crystals and few manganiferous nodules and soft segregations; pH 7.5-9.0. Clear to diffuse to -

B_{22}: Grey to brown (10YR to 7.5YR 5/2 to 4/4 and 6/4); medium heavy to heavy clay; may have common fine to medium distinct grey, red or yellow mottles; strong lenticular; dry very firm to very strong; may have few fine to coarse quartz and ironstained gravel; may have common manganiferous veins, carbonate nodules and soft segregations and gypsum crystals; pH 4.5-9.0. Clear to diffuse to -

D's : EITHER Mixture of clay, weathered sandstone and sand

OR Strongly and coarsely mottled, gley, red and yellow acid clay

Depressions



A_1 or A_p: Dark to grey-brown (10YR to 7.5YR 3/1 to 4/2), dark to grey-brown (dry); light medium to medium heavy clay; weak to moderate 2-10 mm subangular blocky parting to <2 mm granular; dry loose; may have few fine to medium quartz and ironstained gravel; may have few carbonate nodules; pH 7.5-9.0. Clear to gradual to -

B_{21}: Dark to grey-brown (10YR to 7.5YR 3/1 to 5/2); medium heavy to heavy clay; moderate 10-50 mm angular blocky becoming strong lenticular with depth; dry very firm to very strong; may have few fine to medium quartz and ironstained gravel; may have common carbonate nodules and soft segregations and common gypsum crystals; pH 6.0-9.0. Gradual to diffuse to -

B_{22}: Grey to brown (10YR to 7.5YR 5/2 to 4/3); medium heavy to heavy clay; may have many fine to coarse dark, gley and red mottles; strong lenticular; dry very firm to very strong; may have few fine to coarse quartz and ironstained gravel; may have common manganiferous veins, many gypsum crystals and few carbonate nodules and soft segregations; pH 5.0-9.0. Clear to diffuse to -

D's : EITHER Mixture of clay, weathered sandstone and sand

OR Strongly and coarsely mottled, gley, red and yellow acid clay

Notes:
1. Thin bands of sand and individual grains are evident throughout the profiles of both mounds and depressions.
2. The pH decreases with depth in the majority of profiles.
3. The strongly and coarsely mottled clay D? horizon may have neutral pH (7.0-8.0) in the uppermost part.

KENMAR, MELONHOLE PHASE

Major attributes: Similar to Kenmar, except for the following:

- melonhole gilgai (vertical interval .30-1.0 m, horizontal interval 10-30 m);
- may have abundant, fine to coarse, quartz and ironstained gravel on the surface of mounds;
- a generally coarser self-mulching surface in depressions;
- sporadic bleach may be occasionally present below the self-mulch in depressions;
- the strongly and coarsely mottled, acid, gleyed clay may be encountered from 750 mm depth in depressions

Villafranca Soil Type

Major attributes: A hard setting, red, massive, gradational soil with acid to neutral reaction trend overlying ferricrete

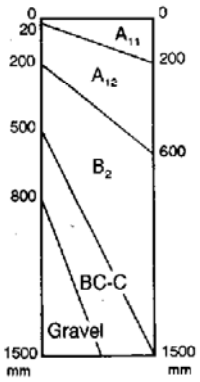
Principal profile forms: Gn2.11, Gn2.12, Um5.52 **Great soil group:** Red earth

Parent material: Cainozoic ferruginised sediments (soil material and gravel)

Landform: Level plains

Predominant vegetation: Queensland grey ironbark, tall to mid-high, open woodland to woodland

Surface features: May have few, fine, ferruginised gravel; hard setting



A_{11}: Red to brown (2.5YR to 7.5YR 3/3 to 4/4), red to brown (dry); loamy sand to clay loam, sandy; massive; dry very weak to moderately weak; may have few fine to medium ferruginised gravel; pH 5.0-7.0. Clear to diffuse to -

A_{12} (where present): Red (10R to 5YR 3/4 to 4/6), red to red-brown (dry); loamy sand to clay loam, sandy; massive to weak structure; dry very weak to moderately firm; may have few fine to medium ferruginised gravel; pH 6.0-7.0. Gradual to diffuse to -

B_2: Red (10R to 5YR 3/4 to 4/6); light sandy clay loam to sandy clay; massive to weak structure; dry moderately weak to very firm; may have few fine to medium ferruginised gravel; pH 6.0-7.5. Clear to diffuse to -

BC (where present): Red to brown (2.5YR to 7.5YR 4/4 to 5/8); loamy sand to sandy clay; massive; may have very abundant fine to medium, ferruginised gravel; pH 6.0-7.5

Note: Profiles with brown A horizons and a yellow B_2 horizon (Gn2.22) rarely occur in broad, flat drainage depressions.

SOIL TYPE: **Lebanon**

SITE NO: S32 A.M.G. REFERENCE: 593 900 mE 7 545 200 mN ZONE 55

GREAT SOIL GROUP: No suitable group (affinities with solodized solonetz/solodic soil)
PRINCIPAL PROFILE FORM: Dy3.32
SOIL TAXONOMY UNIT: Typic Paleargid
FAO UNESCO UNIT: Luvic Xerosol

SLOPE: 0 %
LANDFORM ELEMENT TYPE: Flat
LANDFORM PATTERN TYPE: Level plain

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Nil

DISTURBANCE OF SITE: No effective disturbance other than grazing
VEGETATION
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: Eucalyptus populnea, Eucalyptus papuana

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to .10 m	Greyish brown (5YR4/2) moist, brown (7.5YR4/3) dry; no mottles; sandy clay loam; no coarse fragments; massive; dry; moderately weak; no segregations. Clear to-
A12	.10 to .30 m	Dull brown (7.5YR5/4) moist; no mottles; sandy clay loam; no coarse fragments; massive; dry; moderately weak; no segregations. Abrupt to-
B1sb	.30 to .40 m	Dull orange (7.5YR6/4) moist, dry sporadically bleached; no mottles; sandy clay; very few small pebbles, subrounded unspecified coarse fragments; dry; moderately firm; no segregations. Clear to-
B2	.40 to .70 m	Bright brown (7.5YR5/6) moist; common medium prominent red mottles, few medium faint grey mottles; light medium clay; common small pebbles, subrounded unspecified coarse fragments; dry; very firm; very few fine manganiferous veins.

Depth	1:5 Soil/Water pH @ 40C	EC dS/m @ 40C	Cl % @105C	Particle Size CS	FS	S	C % @ 105C	Exch. Cations CEC	Ca	Mg	Na	K m.eq/100g @ 105C	Total Elements P	K	S % @ 80C	Moistures ADM	33*	1500* % @ 105C	Disp.Ratio R1 @ 40C	R2	Exch Al	Exch Acid m.eq/100g @ 105C	ECEC	pH CaCl2 @ 40C
metres																								
B 0.10	7.1	.05	.001													1.0								
0.10	7.4	.03	.001	17	64	4	15	9	6.4	2.2	.09	.55	.026	.335	.029	0.8		4	.57					
0.20	6.9	.01	.001													0.6								
0.30	6.9	.01	.001	17	63	4	17	6	3.9	1.0	.05	.35	.020	.339	.014	0.7		4	.56					
0.40	7.0	.02	.001													0.9								
0.50	7.0	.03	.002													1.4								
0.60	7.3	.03	.002	12	41	4	44	11	6.6	2.5	.09	.66	.023	.646	.009	1.8		12	.30					
0.70	7.5	.03	.002													2.0								

Depth	Org.C (W&B)	Tot.N	Extr. P Acid	Bicarb.	HCl K	CaCl2 Extr K	P	DTPA-extr. Fe	Mn	Cu	Zn	B	Extractable SO4S	NO3N	NH4N	P Buff Cap	Equil	Alternative Cations CEC	Ca	Mg	Na	K
metres	% @ 105C	% @ 105C	mg/kg @ 105C		meq% @105C	mg/kg @ 105C		mg/kg @ 105C					mg/kg @ 105C			@ 40C	ug/L	m.eq/100g @ 105C				
B 0.10	0.6	.04	5	3	.44			9	16	0.3	0.2											

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol CEC method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol

SOIL TYPE: **Kenmar, melonhole phase**

SITE NO: S43 A.M.G. REFERENCE: 580 600 mE 7 551 200 mN ZONE 55

GREAT SOIL GROUP: No suitable group
PRINCIPAL PROFILE FORM: Uf6.33
SOIL TAXONOMY UNIT: Calciorthid
FAO UNESCO UNIT: Calcic Xerosol

SLOPE: 0 %
LANDFORM ELEMENT TYPE: Upper slope
LANDFORM PATTERN TYPE: Level plain

TYPE OF MICRORELIEF: Melonhole gilgai
VERTICAL INTERVAL: .70 m
HORIZONTAL INTERVAL: 20 m
COMPONENT OF MICRORELIEF SAMPLED: Mound
SURFACE COARSE FRAGMENTS: Many medium pebbles, subrounded unspecified coarse fragments

DISTURBANCE OF SITE: Complete clearing
VEGETATION
STRUCTURAL FORM: Tall sparse shrubland
DOMINANT SPECIES: Apophyllum anomalum, Cenchrus ciliaris

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Firm

HORIZON	DEPTH	DESCRIPTION
A1	0 to .01 m	Brown (7.5YR4/3) moist, dull brown (7.5YR5/3) dry; no mottles; fine sandy medium clay; no coarse fragments; weak <2mm granular; dry; loose; no segregations. Clear to-
B21	.01 to 1.40 m	Dull orange (7.5YR6/4) moist; no mottles; medium heavy clay; very few medium pebbles, subrounded unspecified coarse fragments, few small pebbles, subrounded unspecified coarse fragments; dry; very firm; many coarse carbonate soft segregations, very few medium manganiferous veins. Gradual to-
B22	1.40 to 1.80 m	Dull orange (7.5YR6/4) moist; few medium faint grey mottles, very few fine distinct red mottles; medium heavy clay; very few small pebbles, subrounded unspecified coarse fragments; strong lenticular; dry; moderately strong; common medium manganiferous veins, very few fine carbonate nodules.

Depth	1:5 Soil/Water pH @ 40C	EC dS/m @ 40C	Cl % @105C	Particle Size CS FS S % @ 105C	C	Exch. Cations CEC Ca Mg Na K m.eq/100g @ 105C					Total Elements P K S % @ 80C			Moistures ADM 33* 1500* % @ 105C		Disp.Ratio R1 @ 40C	R2	Exch Al m.eq/100g @ 105C	Exch Acid	ECEC	pH CaCl2 @ 40C
metres																					
B 0.10	8.6	.15	.001																		
0.10	8.7	.13	.001	25 30	5 36	26	26	2.8	.21	.36	.061	.178	.131	5.1	12	.48					
0.20	8.8	.12	.001																		
0.30	9.1	.12	.001	20 24 15	44	25	23	4.6	.47	.15	.033	.075	.073	2.9	12	.27					
0.40	9.3	.12	.001																		
0.50	9.6	.16	.001																		
0.60	9.8	.20	.002	17 21 21	43	25	15	8.3	3.0	.10	.014	.035	.053	3.0	12	.42					
0.70	9.8	.26	.004																		
0.80	9.9	.33	.010																		
0.90	9.8	.41	.017	20 24 15	43	27	11	12	7.0	.10	.011	.042	.060	3.4	13	.64					
1.00	9.8	.52	.028																		
1.10	9.7	.64	.042																		
1.20	9.6	.82	.060	19 25 13	43	31	11	15	11	.10	.011	.039	.059	3.8							
1.30	9.6	.89	.067																		
1.40	9.6	.96	.079																		
1.50	9.0	1.0	.091																		

Depth	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. P Acid Bicarb. mg/kg @ 105C	HCl K meq% @105C	CaCl2 Extr K mg/kg @ 105C	P mg/kg	DTPA-extr. Fe Mn Cu Zn mg/kg @ 105C				B	Extractable SO4S NO3N NH4N mg/kg @ 105C			P Buff Cap	Equil ug/L @ 40C	Alternative Cations CEC m.eq/100g @ 105C	Ca	Mg	Na	K
metres																					
B 0.10	1.4	.09	33 12	.34		12	12	1.3	.26												

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol CEC method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol

SOIL TYPE: **Kenmar, melonhole phase**

SITE NO: S44 A.M.G. REFERENCE: 580 600 mE 7 551 200 mN ZONE 55

GREAT SOIL GROUP: Grey clay
PRINCIPAL PROFILE FORM: Ug5.24
SOIL TAXONOMY UNIT: Typic Torrert
FAO UNESCO UNIT: Pellic Vertisol

SLOPE: 0 %
LANDFORM ELEMENT TYPE: Flat
LANDFORM PATTERN TYPE: Level plain

TYPE OF MICRORELIEF: Melonhole gilgai
VERTICAL INTERVAL: .70 m
HORIZONTAL INTERVAL: 20 m
COMPONENT OF MICRORELIEF SAMPLED: Depression
SURFACE COARSE FRAGMENTS: Very few coarse pebbles, subangular unspecified coarse fragments

DISTURBANCE OF SITE: Complete clearing
VEGETATION
STRUCTURAL FORM: Tall sparse shrubland
DOMINANT SPECIES: Apophyllum anomalum, Cenchrus ciliaris

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Periodic cracking, self-mulching

HORIZON	DEPTH	DESCRIPTION
A1	0 to .02 m	Greyish yellow-brown (10YR4/2) moist, brownish grey (10YR4/1) dry; no mottles; medium heavy clay; no coarse fragments; strong 5-10mm subangular blocky; dry; loose; no segregations. Clear to-
B21	.02 to .30 m	Brownish grey (7.5YR4/1) moist; no mottles; medium heavy clay; very few medium pebbles, subrounded unspecified coarse fragments; dry; moderately strong; common medium carbonate soft segregations. Clear to-
B22	.30 to .80 m	Brownish grey (7.5YR4/1) moist; no mottles; heavy clay; very few medium pebbles, subrounded unspecified coarse fragments; strong lenticular; dry; moderately strong; few medium carbonate nodules. Diffuse to-
B23	.80 to 1.70 m	Greyish yellow-brown (10YR5/2) moist, brownish grey (7.5YR4/1) moist; few medium prominent red mottles; heavy clay; very few medium pebbles, subrounded unspecified coarse fragments; strong lenticular; dry; moderately strong; few coarse manganiferous cutans.

Depth metres	1:5 Soil/Water pH @ 40C	EC dS/m @105C	Cl % @105C	Particle Size CS FS S % @ 105C	C	Exch. Cations CEC Ca Mg Na K m.eq/100g @ 105C					Total Elements P K S % @ 80C			Moistures ADM 33* 1500* % @ 105C		Disp.Ratio R1 R2 @ 40C		Exch Exch ECEC Al Acid m.eq/100g @ 105C	pH CaCl2 @ 40C
B 0.10	8.5	.19	.003																
0.10	8.5	.22	.004	16 14 16	50	51	43	5.9	.70	.67	.062	.145	.074	6.4	20	.56			
0.20	8.8	.18	.001																
0.30	8.8	.18	.001	22 17 14	47	44	36	7.4	2.0	.17	.023	.056	.036	5.3	18	.44			
0.40	8.9	.15	.001																
0.50	8.9	.12	.002																
0.60	8.7	.21	.013	26 20 14	44	38	25	8.5	5.3	.15	.012	.043	.024	5.3	18	.84			
0.70	8.7	.28	.019																
0.80	7.9	.42	.041																
0.90	7.5	.47	.048	30 22 11	38	32	17	8.4	7.6	.10	.008	.027	.031	4.0	16	.92			
1.00	6.7	.61	.066																
1.10	6.4	.64	.070																
1.20	6.0	.68	.073	36 22 11	32	27	11	7.5	7.7	.10	.008	.029	.039	3.1					
1.30	5.8	.73	.081																
1.40	5.6	.87	.104																
1.50	5.5	.91	.111																

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. P Acid mg/kg @ 105C	Bicarb.	HCl K meq% @105C	CaCl2 Extr K mg/kg @ 105C	P	DTPA-extr. Fe Mn Cu Zn mg/kg @ 105C	B	Extractable SO4S NO3N NH4N mg/kg @ 105C	P Buff Cap @ 40C	Equil ug/L	Alternative Cations CEC Ca Mg Na K m.eq/100g @ 105C
B 0.10	1.0	.10	53	53	.76			26 6.5 1.8 .46					
0.10													49 5.3 .66 .60
0.30													42 6.9 1.9 .15
0.60													24 8.0 5.7 .14
0.90													16 7.8 8.7 .09
1.20													11 7.1 9.2 .07

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol CEC method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol
Alternative cation method: Extraction with 1M NH_4Cl at pH 7

SOIL TYPE: **Heyford**

SITE NO: S33 A.M.G. REFERENCE: 594 000 mE 7 536 800 mN ZONE 55

GREAT SOIL GROUP: Solodized solonetz/solodic soil SLOPE: 0.5 %
PRINCIPAL PROFILE FORM: Dy3.43 LANDFORM ELEMENT TYPE: Plain
SOIL TAXONOMY UNIT: Natrargid LANDFORM PATTERN TYPE: Gently undulating plains
FAO UNESCO UNIT: Orthic Solonetz

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Very few small pebbles, subrounded unspecified coarse fragments

DISTURBANCE OF SITE: No effective disturbance other than grazing
VEGETATION
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: Eucalyptus populnea, Cassia brewsteri

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .10 m	Brown (7.5YR4/3) moist, dull brown (7.5YR6/3) dry; no mottles; sandy loam; no coarse fragments; massive; dry; moderately firm; no segregations. Clear to-
A2cb	.10 to .25 m	Dull orange (7.5YR6/4) moist, dull orange (7.5YR7/3) dry; no mottles; sandy loam; no coarse fragments; massive; dry; moderately firm; no segregations. Abrupt to-
B21	.25 to .50 m	Orange (7.5YR6/6) moist, greyish brown (7.5YR6/2) moist; medium clay; few medium pebbles, subangular sandstone; dry; moderately strong; common medium manganiferous veins. Clear to-
B22	.50 to 1.10 m	Bright brown (7.5YR5/6) moist; few fine prominent red mottles, few fine distinct grey mottles; medium clay; no coarse fragments; dry; moderately strong; common coarse carbonate soft segregations, few coarse manganiferous veins. Clear to-
BC	1.10 to 1.30 m	Orange (7.5YR6/6) moist; common coarse distinct gley mottles; abundant fragments, sandstone; no segregations.

Depth	1:5 Soil/Water pH @ 40C	EC dS/m @105C	Cl % @105C	Particle Size CS FS S % @ 105C	C	Exch. Cations CEC Ca Mg Na K m.eq/100g @ 105C	Total Elements P K S % @ 80C	Moistures ADM 33* 1500* % @ 105C	Disp.Ratio R1 @ 40C	R2	Exch Exch ECEC Al Acid m.eq/100g @ 105C	pH CaCl2 @ 40C
B 0.10	6.8	.02	.001					0.7				
0.10	7.5	.02	.001	16 70 4	12	6 4.1 1.6 .05 .53	.026 .839 .011	0.7	3	.63		
0.20	7.2	.02	.001					0.4				
0.25	7.4	.03	.002	20 67 6	10	4 2.4 1.0 .05 .34	.017 .833 .026	0.4	2	.74		
0.40	7.0	.41	.061					2.2				
0.50	8.0	.44	.064					2.3				
0.60	9.1	.55	.055	8 48 4	42	14 5.8 5.7 2.5 .68	.022 1.73 .040	1.8	15	.85		
0.70	9.2	.57	.056					1.9				
0.80	9.3	.59	.058					1.9				
0.90	9.3	.61	.061	14 43 7	37	13 5.2 8.1 2.6 .50	.020 1.85 .046	1.8	13	.88		
1.00	9.4	.62	.061					1.9				
1.10	9.4	.63	.063					1.6				
1.20	9.4	.66	.069	10 44 11	37	13 4.4 8.3 3.2 .45	.032 2.43 .023	1.7				
1.30	9.3	.65	.068					1.8				
1.35	9.4	.68	.073					2.0				

Depth	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. P Acid Bicarb. mg/kg @ 105C	HCl K meq% @105C	CaCl2 Extr K mg/kg @ 105C	P	DTPA-extr. Fe Mn Cu Zn mg/kg @ 105C	B	Extractable SO4S NO3N NH4N mg/kg @ 105C	P Buff Equil Cap ug/L @ 40C	Alternative Cations CEC Ca Mg Na K m.eq/100g @ 105C
B 0.10	0.6	.03	7 3	.40		14	13 0.4 0.6				

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol CEC method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol

SOIL TYPE: **Fletcher**

SITE NO: S36 A.M.G. REFERENCE: 571 800 mE 7 545 200 mN ZONE 55

GREAT SOIL GROUP: No suitable group
PRINCIPAL PROFILE FORM: Uf6.31
SOIL TAXONOMY UNIT: Calciorthid
FAO UNESCO UNIT: Calcic Xerosol

SLOPE: 2 %
LANDFORM ELEMENT TYPE: Lower slope
LANDFORM PATTERN TYPE: Level plain

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Very few small pebbles, subrounded quartz

DISTURBANCE OF SITE: Complete clearing
VEGETATION
STRUCTURAL FORM: Tall tussock grassland
DOMINANT SPECIES: Cenchrus ciliaris

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .05 m	Dark reddish brown (5YR3/3) moist; no mottles; sandy medium heavy clay; no coarse fragments; moist; moderately firm; no segregations. Clear to-
B21	.05 to .35 m	Dark reddish brown (5YR3/4) moist; no mottles; sandy heavy clay; very few small pebbles, subangular unspecified coarse fragments; moist; moderately firm; very few medium carbonate nodules. Gradual to-
B22	.35 to 1.00 m	Dull reddish brown (5YR4/4) moist; few fine distinct dark mottles; heavy clay; few small pebbles, subangular unspecified coarse fragments; moderately moist; very firm; common coarse carbonate soft segregations, very few coarse carbonate nodules. Clear to-
B23	1.00 to 1.25 m	Reddish brown (5YR4/6) moist, brown (7.5YR4/6) moist; no mottles; sandy medium clay; few small pebbles, subangular unspecified coarse fragments; dry; very firm; common carbonate soft segregations, few coarse carbonate nodules. Clear to-
B24	1.25 to 1.50 m	Brown (7.5YR4/4) moist; no mottles; sandy medium clay; no coarse fragments; dry; moderately firm; many carbonate soft segregations, few coarse carbonate nodules.

Depth	1:5 Soil/Water pH	EC	Cl	Particle Size CS	FS	S	C	Exch. Cations CEC	Ca	Mg	Na	K	Total Elements P	K	S	Moistures ADM 33*	1500*	Disp.Ratio R1	R2	Exch Al	Exch Acid	ECEC	pH CaCl2
metres	@ 40C	dS/m	@105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C		@ 40C		m.eq/100g @ 105C			@ 40C
B 0.10	7.5	.04	.001																				
0.10	7.4	.03	.001	29	31	7	33	29	16	9.8	.10	.41	.030	.255	.022	3.0	13	.41					
0.20	7.5	.03	.001													3.7							
0.30	7.7	.06	.001	27	30	8	37	34	19	11	.20	.21	.021	.177	.018	3.9		.40					
0.40	8.7	.11	.001													3.8							
0.50	8.8	.11	.001													3.7							
0.60	8.9	.12	.001	21	30	16	32	30	14	14	.39	.17	.018	.181	.021	2.6	14	.49					
0.70	8.9	.13	.001													2.7							
0.80	8.9	.14	.001													2.8							
0.90	9.1	.15	.002	22	35	12	30	27	10	16	.74	.22	.019	.259	.018	3.1	13	.51					
1.00	9.1	.16	.003													3.0							
1.10	9.1	.15	.002													2.8							
1.20	9.2	.17	.003	25	38	11	25	23	7.1	16	.95	.17	.021	.306	.019	2.0							
1.30	9.2	.20	.005													1.9							
1.40	9.2	.23	.008													1.7							
1.50	9.2	.25	.012																				

Depth	Org.C (W&B)	Tot.N	Extr. P Acid	Bicarb.	HCl K	CaCl2 Extr K	P	DTPA-extr. Fe	Mn	Cu	Zn	B	Extractable SO4S	NO3N	NH4N	P Buff	Equil	Alternative Cations CEC	Ca	Mg	Na	K
metres	% @ 105C	% @ 105C	mg/kg @ 105C		meq% @105C	mg/kg @ 105C		mg/kg @ 105C					mg/kg @ 105C			Cap @ 40C	ug/L	m.eq/100g @ 105C				
B 0.10	0.8	.07	9	4	.45			11	13	0.7	0.2											

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol CEC method: Extraction with 1M NH_4Cl at pH 8.5 in 60% ethanol

SOIL TYPE: **Cherwell**

SITE NO: S13 A.M.G. REFERENCE: 603 300 mE 7 541 500 mN ZONE 55

GREAT SOIL GROUP: Lithosol
PRINCIPAL PROFILE FORM: Uc1.24
SOIL TAXONOMY UNIT: Lithic Torriorthent
FAO UNESCO UNIT: Haplic Xerosol

SLOPE: 10 %
LANDFORM ELEMENT TYPE: Upper slope
LANDFORM PATTERN TYPE: Rolling low hills

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Very few cobbles, angular tabular sandstone

DISTURBANCE OF SITE: No effective disturbance other than grazing
VEGETATION
STRUCTURAL FORM: Tall woodland
DOMINANT SPECIES: Acacia shirleyi, Alphitonia excelsa, Aristida species

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to .25 m	Brownish black (7.5YR3/2) moist; no mottles; loamy coarse sand; few medium pebbles, subangular sandstone, very few coarse pebbles, angular tabular sandstone; massive; moist; very weak; no segregations. Clear to-
A12	.25 to .40 m	No mottles; coarse sand; many medium pebbles, subrounded sandstone, very few coarse pebbles, subangular sandstone; massive; moist; very weak; no segregations.

Depth	1:5 Soil/Water pH	EC	Cl	Particle Size CS	FS	S	C	Exch. Cations CEC	Ca	Mg	Na	K	Total Elements P	K	S	Moistures ADM 33*	1500*	Disp.Ratio R1	R2	Exch Al	Exch Acid	ECEC	pH CaCl2
metres		dS/m	%	%				m.eq/100g					%			%				m.eq/100g			
	@ 40C		@105C	@ 105C				@ 105C					@ 80C			@ 105C		@ 40C		@ 105C			@ 40C
B 0.10	4.8	.03	.001																				
0.10	5.1	.02	.001	55	28	6	11	16	1.0	0.3	3.7	.08	.020	1.01	.022	0.2	5	.53					
0.20	4.9	.02	.001													0.8							

Depth	Org.C (W&B)	Tot.N	Extr. P Acid	Bicarb.	HCl K	CaCl2 Extr K	P	DTPA-extr. Fe	Mn	Cu	Zn	B	Extractable SO4S	NO3N	NH4N	P Buff Cap	Equil	Alternative Cations CEC	Ca	Mg	Na	K
metres	%	%	mg/kg		meq%	mg/kg		mg/kg					mg/kg				ug/L	m.eq/100g				
	@ 105C	@ 105C	@ 105C		@105C	@ 105C		@ 105C					@ 105C			@ 40C		@ 105C				
B 0.10	1.4	.09	5	2	.41			36	10	0.2	0.6											

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 7 CEC method: Extraction with 1M NH_4Cl at pH 7

SOIL TYPE: **Villafranca**

SITE NO: S26 A.M.G. REFERENCE: 589 600 mE 7 546 700 mN ZONE 55

GREAT SOIL GROUP: Red earth
PRINCIPAL PROFILE FORM: Gn2.12
SOIL TAXONOMY UNIT: Torrox
FAO UNESCO UNIT: Orthic Ferralsol?

SLOPE: 0 %
LANDFORM ELEMENT TYPE: Flat
LANDFORM PATTERN TYPE: Level plain

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Nil

DISTURBANCE OF SITE: No effective disturbance other than grazing
VEGETATION
STRUCTURAL FORM: Tall open woodland
DOMINANT SPECIES: Eucalyptus polycarpa, Eucalyptus papuana, Eucalyptus erythrophloia, Eucalyptus drepanophylla, Bursaria incana, Aristida species, Heteropogon contortus

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to .03 m	Dull reddish brown (2.5YR4/4) moist, bright reddish brown (5YR5/6) dry; no mottles; clay loam, sandy; no coarse fragments; massive; dry; very firm; no segregations. Clear to-
A12	.03 to .25 m	Reddish brown (10R4/4) moist; no mottles; clay loam,sandy; no coarse fragments; weak; dry; very firm; no segregations. Diffuse to-
B2	.25 to 1.30 m	Red (10R4/6) moist; no mottles; sandy clay; few small pebbles, subrounded gravel; weak; dry; very firm; no segregations. Clear to-
D	1.30 to 1.50 m	Very abundant medium pebbles, rounded gravel; no segregations.

Depth	1:5 Soil/Water pH	1:5 Soil/Water EC	1:5 Soil/Water Cl	Particle Size CS	Particle Size FS	Particle Size S	Particle Size C	Exch. Cations CEC	Exch. Cations Ca	Exch. Cations Mg	Exch. Cations Na	Exch. Cations K	Total Elements P	Total Elements K	Total Elements S	Moistures ADM	Moistures 33*	Moistures 1500*	Disp.Ratio R1	Disp.Ratio R2	Exch Al	Exch Acid	ECEC	pH CaCl2
metres		dS/m	%		%			m.eq/100g						%			%					m.eq/100g		
	@ 40C	@40C	@105C		@ 105C			@ 105C						@ 80C			@ 105C		@ 40C			@ 105C		@ 40C
B 0.10	6.7	.05	.002					6	3.9	1.5	.04	.83												
0.10	6.0	.04	.001	25	43	8	25	6	2.6	1.3	.02	.62	.034	.241	.024	1.1		7	.37					
0.20	6.0	.04	.001																					
0.30	6.3	.03	.001	23	41	5	31	4	2.4	1.1	.02	.48	.034	.239	.023	1.0		8	.28					
0.40	6.4	.03	.002																					
0.50	6.5	.03	.002																					
0.60	6.5	.03	.002	21	38	6	37	5	3.3	1.4	.02	.39	.027	.275	.010	1.1		9	.24					
0.70	6.5	.02	.002																					
0.80	6.4	.02	.001																					
0.90	6.3	.02	.001	21	38	6	36	3	1.8	1.3	.02	.25	.028	.283	.012	1.2		9	.11					
1.00	6.3	.02	.001																					
1.10	6.5	.02	.001																					
1.20	6.6	.02	.001	20	39	6	30	4	1.7	1.8	.02	.18	.026	.262	.009	1.2								
1.30	6.9	.02	.001																					
1.40	6.9	.02	.001																					
1.50	7.1	.02	.001																					
1.60	7.3	.03	.001	35	29	7	27	5	2.0	2.4	.02	.17	.039	.148	.011	1.5								

Depth	Org.C (W&B)	Tot.N	Extr. P Acid	Extr. P Bicarb.	HCl K	CaCl2 Extr K	CaCl2 Extr P	DTPA-extr. Fe	DTPA-extr. Mn	DTPA-extr. Cu	DTPA-extr. Zn	DTPA-extr. B	Extractable SO4S	Extractable NO3N	Extractable NH4N	P Buff Cap	P Equil	Alternative Cations CEC	Alternative Cations Ca	Alternative Cations Mg	Alternative Cations Na	Alternative Cations K
metres	%	%	mg/kg		meq%	mg/kg		mg/kg					mg/kg				ug/L	m.eq/100g				
	@ 105C	@ 105C	@ 105C		@105C	@ 105C		@ 105C					@ 105C			@ 40C		@ 105C				
B 0.10	0.7	.04	5		.76			18	54	0.9	0.1											

* -33kPa (-0.33bar) and -1500kPa (-15 bar) using pressure plate apparatus.
Cation method: Extraction with 1M NH_4Cl at pH 7 CEC method: Extraction with 1M NH_4Cl at pH 7

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