APPENDIX B6 SOIL MANAGEMENT PROTOCOL

Land Resource Assessment and Management Pty. Ltd.

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SunWater Nathan Dam and pipeline project
Soil Management Protocols: Wandoan to Warra section

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1. Introduction

1.1 Background

SunWater Ltd (SunWater) is the proponent for the Nathan Dam and pipeline project. The project involves constructing and operating Nathan Dam on the Dawson River in Central Queensland and transporting water from the dam via a trunk pipeline approximately 218 km to Warra.

SunWater has submitted an Environmental Impact Statement (EIS) for the project to the Queensland Coordinator-General and, following a period of public consultation, has received a request from the Coordinator-General for supplementary information.

In response to this request, SunWater has commissioned Land Resource Assessment & Management Pty Ltd (LRAM) to prepare soil management protocols that will address many of the land management issues raised during public consultation. The soil management protocols are to apply to all new sections of the pipeline, including the 146 km section of the pipeline between Wandoan and Warra.

LRAM has previously developed soil management protocols for two CSG companies operating in the Surat and Bowen Basins. These protocols were developed in response to regulatory conditions placed on the CSG collection and gathering operations as part of the environmental authorities issued to each company. The CSG operations addressed by the management protocols include construction and operation of gas and water gathering lines.

The style, layout and content of these previous protocols has been reviewed and endorsed by the Queensland Government and the landscape, pipeline construction and operational activities addressed by them have much in common with the SunWater pipeline. Therefore, these protocols have been modified by LRAM for application to the Wandoan to Warra section of the pipeline corridor.

1.2 Purpose of the protocols

The soil management protocols are designed to assist SunWater and its contractors with:

- identification of distinct soil management groups along the pipeline corridor;
- mapping the distribution of these soil management groups within the corridor;
- determining the environmental risk for each soil management group due to particular construction and operation activities associated with the pipeline; and
- identifying appropriate management strategies to implement so that environmental impact is minimised.

Section 2 of this document provides a soil reference for the range of soil management groups that may be encountered along the pipeline corridor.

A Soil Identification Protocol (section 4) describes the process for identifying these soil management groups and a Soil Mapping Protocol (section 3) provides the mechanism for mapping their distribution.

A Risk Assessment and Management Protocol provides the process for matching a particular soil management group to be disturbed against each planned activity and then describes the range of management strategies that are to be implemented (section 5 and attached Schedules).

2. Soil management groups

2.1 Basis for soil management groups

A review of existing soil studies shows that more than 200 'soils' have been identified and described as part of the regional land resource surveys conducted within the Surat and Bowen Basins[1]. Additional to these regional soils, even more soil types have been delineated during detailed soil surveys of key areas within both basins.

Each of the 'soils' delineated will have attributes that distinguish them from the other soils but the distinguishing attributes may not be relevant when comparing soil suitability for, or impact from, a particular land use. In fact, many of these soils have similar features in terms of potential impacts arising from activities undertaken associated with construction and operation of a water delivery pipeline.

LRAM has previously reviewed the range of individual soils within the entire Surat and Bowen Basins and amalgamated this range into 11 to 12 basic soil management groups for use by individual CSG companies. Twelve basic soil management groups were also identified by LRAM for Queensland Department of Environment and Heritage Protection (DEHP) use during its assessment process of applications for beneficial use approval of irrigating treated CSG water.

The pipeline corridor traverses three regional land resource surveys and information available from these surveys indicates that eight of the twelve DEHP basic soil management groups are common along the corridor and the other four groups may also be present in small areas. There appear to be no soils described in the regional surveys that do not fit one of the twelve soil management groups. Thus, these soil management groups provide an appropriate basis for:

- describing the soil variation within the Wandoan to Warra pipeline corridor;
- assessing the soil related impacts of constructing and operating the pipeline; and
- determining appropriate management strategies.

2.2 Soil Reference

There are twelve soil management groups that form a soil reference for the pipeline corridor as shown in Table 1.

Each soil management group in the soil reference consists of several individual soils identified during regional and more detailed surveys but the individual soils have similar profile features as well as similar chemical and physical properties. So, from a management point of view each soil management group will require similar inputs to ensure environmental impacts on both soil and water quality and amenity are minimised.

Descriptions of the soil management groups are provided in Appendix A and a soil key to these groups is presented in Appendix B. An explanation of how to use the soil key is given in section 4.

Technical terms used in the soil reference including are described in the Glossary in Appendix F.

[1] Copies of many of these reports covering the western cropping zone in which the Bowen and Surat Basins occur can be accessed via the Queensland Government natural resources library at qldgov.softlinkhosting.com.au/liberty/libraryHome.do

Table 1. Soil reference for the SunWater pipeline corridor

Soil management group [1]	Distinguishing features [2,3,4,5,6,7,8]
Shallow soils – all profiles <1 m to weathered rock, hard rock or continuous gravel layer	
Shallow sands and loams	Shallow, often rocky soils on uplands that have either a uniform "sandy" profile or a uniform, "loamy" profile
Shallow clay loams and light clays [9]	Shallow, often rocky soils on uplands that have: - either a uniform, "clay loam" profile - or a uniform, fine textured profile of light clay to light medium clay - or a gradational texture profile in which a sandy clay loam, clay loam, silty clay loam and/or clay loam, sandy surface layer gradually merges into structured, clay subsoil The gradational soils are shallow forms of *Structured earths* (as described below)
Shallow medium-heavy clays [10]	Shallow, occasionally rocky soils on uplands that have a uniform, fine textured profile with medium to heavy clay texture below the surface layer Profiles may be either "non-cracking clays" that do not develop vertical cracks at or just below the surface as they dry or shallow forms of *Deep cracking clays* (as described below)
Deep soils – all profiles ≥1 m to weathered rock, hard rock or continuous gravel layer	
Deep sands and sandy loams	Deep soils on gently undulating uplands and on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow with a uniform "sandy" profile
Deep loams and clay loams	Deep soils on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow with uniform "loam to clay loam" profile
Structured earths	Deep soils mainly on undulating uplands but occasionally on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow with: - either a gradational texture profile in which surface texture is "loam to clay loam" and then gradually increases with depth, and with moderate to strong structure in the subsoil - or a uniform, fine textured profile with light clay to light medium clay surface texture and moderate to strong structure in the clay subsoil Fine textured profiles also have relatively fine structure (individual peds are predominantly ≤20 mm) and do not develop vertical cracks at or just below the surface as they dry and are often referred to as "non-cracking clays"
Deep cracking clays	Deep soils with fine textured profiles of light clay to heavy clay texture and coarse structure (individual peds are predominantly ≥50 mm) at depth; most profiles shrink and swell with changing moisture content but some "non-cracking clays" do not

Soil management group [1]	Distinguishing features [2,3,4,5,6,7,8]
Melonhole clays	Deep soils on very gently undulating uplands with fine textured profiles of light medium clay to heavy clay texture that exhibit a capacity to shrink as they dry and swell during wetting and have melonhole gilgai microrelief
Shallow to deep soils – profiles with variable depth to weathered rock, hard rock or continuous gravel layer	
Massive earths	Shallow to deep soils on gently to strongly dissected uplands with gradational texture profiles in which surface texture is "sandy" or "loamy " and then gradually increases with depth though structure remains massive in the subsoil; shallow profiles are often rocky
Non-dispersive TC soils	Shallow to deep soils with texture contrast (TC) profiles with surface and subsurface layers of "sandy" or "loam to clay loam" texture suddenly changing into non-dispersive clay subsoil
Thin-surfaced, dispersive TC soils	Shallow to deep soils with texture contrast (TC) profiles with surface and subsurface layers of "sandy" or "loam to clay loam" texture suddenly changing into dispersive clay subsoil; total thickness of the surface and subsurface layers is ≤200 mm
Thick-surfaced, dispersive TC soils	Shallow to deep soils with texture contrast (TC) profiles with surface and subsurface layers of "sandy" or "loam to clay loam" texture suddenly changing into dispersive clay subsoil; total thickness of the surface and subsurface layers is >200 mm

Notes:

1. Adapted from draft guideline for beneficial use approval of irrigating treated CSG water being prepared by DEHP.
2. Shallow soils overlie bedrock at <1 m whereas deep soils have bedrock at ≥1 m depth below the ground surface.
3. Soil profiles subject to stream flooding and concentrated overland flow often overlie buried layers of different deposition which often have different texture, structure and colour.
4. “sandy” refers to coarse texture grades of sand; loamy sand; clayey sand; sandy loam.
5. "loamy" refers to medium texture grades of loam, silty loam and/or sandy clay loam.
6. "clay loam" refers to medium texture grades of clay loam, silty clay loam and/or clay loam, sandy.
7. “loam to clay loam” refers to medium texture grades of loam; silty loam; sandy clay loam; clay loam; clay loam, sandy; silty clay loam.
8. Fine textured profiles have uniform clay texture which may vary from light clay to heavy clay.
9. Shallow clay loams and light clays include shallow forms of *Structured earths*.
10. Shallow medium-heavy clays include shallow forms of *Deep cracking clays*.

3. Soil Mapping Protocol

3.1 Purpose of this protocol

The Soil Mapping Protocol describes the procedure to be followed when mapping the distribution of soil management groups along the pipeline corridor and when delineating the boundary between two different groups.

The protocol establishes the:

- appropriate scale for mapping the distribution of soil management groups;
- number of field inspections required for the desired mapping scale; and
- proportion of field inspections that need to be detailed or only check sites.

3.2 An appropriate mapping scale

Australian guidelines for surveying soils (McKenzie et al. 2008) provide a general guide on appropriate mapping scales for assessment of soil suitability and planning for various types of land uses. The guidelines recommend a scale of 1:10,000 to 1:50,000 as being appropriate for strategic planning of intensive land use developments on small areas of land.

3.3 An adequate intensity of field inspection

The Australian guidelines (McKenzie et al. 2008) recommend appropriate densities for soil site inspection at different mapping scales. The guidelines determine site density on an area basis and Table 2 shows the minimum acceptable density for soil mapping at a scale varying from 1:10,000 to 1:50,000.

For the Wandoan to Warra pipeline, the width of the corridor will vary from 30 m during construction to 15 m during the operational phase. This will create a disturbance on 1.5 to 3 ha of land for every km of pipeline.

Table 2. Recommended site inspection for 1:10,000 to 1:50,000 scale mapping

Mapping scale	Site inspection density		
	- minimum acceptable area per site [1]	- minimum acceptable km of pipeline per site [1]	- LRAM recommended [2]
1:10,000	4 ha	1.3 km	1 site per 200 m
1:25,000	25 ha	8.3 km	1 site per 500 m
1:50,000	100 ha	33.3 km	1 site per 1 km

Notes:

1. Minimum acceptable is determined according to the Australian guidelines (McKenzie et al. 2008).
2. Recommended site density to provide adequate information for a narrow, linear corridor.

The recommended minimum density of sites as per the Australian guidelines results in only one inspection every 1.3 to 33 kilometres along the pipeline corridor. Such densities will not adequately inform SunWater or the construction contractor of the potential impacts and risks associated with these activities.

Therefore, site density for field inspection has been modified for the pipeline corridor to incorporate a requirement for:

- the entire pipeline route to be driven along and boundaries between different soils to be delineated at a mapping scale intensity of at least 1:50,000;

- soil inspection to be undertaken where any surface features indicate a change in soil type (see section 4); with
- an overall site inspection density to be maintained at a minimum of one soil type per 1 km.

3.4 Soil observations undertaken at a field inspection site

A soil management group may contain several individual soils that would be separated during traditional soil survey but all these individual soils will have similar profile features as well as similar chemical and physical properties (see section 2.2).

Thus, mapping the distribution of these soil management groups is not aimed at producing a traditional soil map and only sufficient information need be collected to distinguish between each of the 12 groups. The Soil Identification Protocol (section 4) lists two different types of inspection sites:

- reference sites with detailed soil profile description; and
- check sites which confirm that the site and profile features match a previously recorded reference site.

A check site may involve either:

- observation of surface features only; or
- exposing and recording soil profile features to a depth of 100-500 mm for a smaller subset of sites.

Many soil management groups can be distinguished on the basis of surface features alone and most check sites may not require exposing a soil profile. However for a substantial subset of sites, a check site will involve exposing and recording soil profile features to a depth of 100-500 mm.

3.5 Proportion of different soil observations

Based on the Australian guidelines for soil survey at 1:10,000 to 1:50,000 mapping scale (McKenzie et al. 2008), site inspections need to be undertaken in the following proportions:

- a minimum 10% of sites are to be reference sites; and
- a maximum 90% of all sites will be check sites.

The Australian guidelines also recommend that a subset of the reference sites should be sampled for laboratory analysis to adequately describe relevant soil chemical and soil physical attributes. Following these guidelines will ensure that a comprehensive baseline dataset is established.

Thus, some reference sites should be selected for laboratory analysis of every soil layer within the soil profile. Selection is to be undertaken to ensure that each of the soil management groups identified is sampled. The total number of analysed profiles will be a minimum 1% of all sites.

4. Soil Identification Protocol

4.1 Purpose of this protocol

The Soil Identification Protocol provides a procedure for obtaining accurate soil identification at a field site. The Soil Identification Protocol describes the procedure for:

- selecting an appropriate site to represent an area;
- exposing a soil profile at the site;
- describing the exposed soil profile;
- determining if the soil profile features match one of the soil management groups listed in the Soil Reference; and
- sampling all or part of the soil profile for laboratory analysis (if necessary).

4.2 Selecting a representative site

Soil features can vary over short distances according to position in the landscape and microrelief on the land surface. Because of this potentially large spatial variation, it is critical to choose a site for inspecting soil features that is representative of the area being investigated.

Undisturbed areas

In areas that are predominantly undisturbed and have a natural land surface it is essential to avoid the following:

- road sides, access tracks and fences where there is evidence of earthworks;
- contour and diversion banks and their immediate surrounds from which soil may have been removed to build the banks;
- any raised areas, especially with regular straight or circular sides, which may have been created by human activity;
- small mounds within an otherwise flat surface as these may be caused by mechanical disturbance, may be ash beds from burned timber stacks or represent degraded termite mounds;
- artificial drains and their immediate surrounds on which the excavated soil from the drains may have been dumped;
- very small closed depressions within an otherwise flat surface (often caused by removal of tree stumps or fence posts); and
- narrow, shallow open depressions which may be where run-off water or run-on water concentrates and flows (however large open depressions covering a substantial area should be inspected as they may contain a different soil management group to the surrounding area).

Disturbed areas

Where a significant area being traversed by the corridor has been disturbed, it is essential to describe the soil features as they occur – not what may have been there prior to disturbance.

For example, areas with sheet and rill erosion should not be avoided if the erosion is characteristic of a substantial area. However, when describing the soil profile, allowance should be made for the thickness of surface material that has been removed when determining which soil management group is present.

Gilgai microrelief

Parts of the pipeline corridor have gilgai microrelief which is a natural soil feature associated with non-rigid soils (which shrink and swell with changing moisture content), often referred to as cracking clays. Gilgai consist of mounds and depressions, sometimes separated by an almost planar ground surface. A more detailed description of gilgai is given in the Australian Soil and Land Survey Field Handbook (The NCST 2009).

If soil inspection is to be done within an area of gilgai microrelief then two or more inspections may be required at one location to determine the range in soil properties between the different gilgai components.

If the area to be investigated contains only sporadic gilgai depressions and/or mounds then a representative site should be chosen within the mainly flat land surface rather than in a depression or on a mound.

4.3 Exposing a soil profile

A soil profile is a sequence of distinctive soil layers, referred to as horizons, which are roughly parallel to the earth's surface. Diagrammatically, a soil profile represents a vertical section taken from the natural land surface through all layers down to the material from which the soil has formed or down to buried material.

However, in most instances a soil profile is described to a maximum depth if underlying parent material or buried layers are not encountered first. The maximum depth is determined by the depth to which the intended land use is likely to disturb the soil.

Soil cores, pits, road cuttings and even gully banks can be used to describe a soil profile.

Hydraulic and mechanical drilling machines which extract an undisturbed core can be used or a hand-held auger can be used to dig a disturbed soil core. The most convenient auger size to use is 38-50 mm for an undisturbed core and 50-75 mm for hand-held augers.

If using a pit, cutting or bank, a fresh surface should be cut as close to vertical as possible and at least 50 mm into the exposed face. Cutting a fresh face ensures that:

- various soil layers are not obscured by soil material that has been dislodged from the top and fallen over the face;
- fresh colours that have not been faded by weathering at the surface are exposed; and
- soil samples taken for field testing and or laboratory analysis are from fresh material that has not been altered by weathering at the surface.

4.4 Describing the soil profile

A soil profile and its associated landform and land surface features should be described using the standard terminology provided in the Australian Soil and Land Survey Field Handbook (The NCST 2009). This handbook is generally referred to as the "yellow book". Important technical terms are also explained in the Glossary at Appendix F.

Identifying soil layers

A standard procedure should always be followed when describing a soil profile:

Step 1 Identify any layers where obvious variations in features occur down the profile such as colour, clay content, hardness, gravel content and moisture content (see Figure 1).

Step 2 Inspect each layer sequentially from the surface down and collect more detailed descriptions of the important soil features within each layer.

If there are no obvious layers then check for important soil features that are not obvious such as soil texture, consistence and pH at regular intervals down the profile. If differences are observed, then recheck at smaller intervals until the boundaries to each different layer are located. Record the upper and lower depth limit to each layer and the important soil features within each layer.

Step 3 When all layers have been described in sufficient detail determine whether any layers are significantly different from those above and below and give a layer name or horizon designation to each layer as described below.

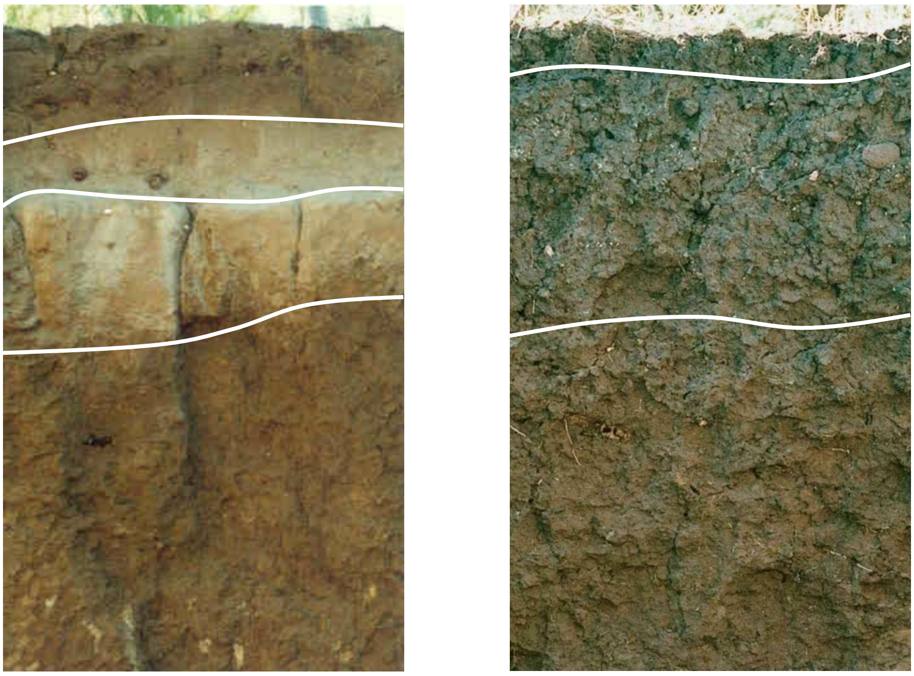

Figure 1. Examples of exposed soil profile with layers delineated

Naming soil layers

For purposes of identifying soil management groups, the following soil layers (and equivalent horizon names) need to be recognised, separated and named:

- Surface layer (A1 horizon)
  - extending down from the ground surface and is usually darker than any other layer below;
- Subsurface layer (A2 horizon)
  - a paler or bleached layer below the surface layer and above the subsoil;
- Subsoil (B horizon)
  - a concentration of clay, iron or aluminium oxides or with stronger colour than layers above;
- Buried layer (D horizon)
  - formed by older deposition than, and distinctly different from, the soil profile above;
- Bedrock (C and R horizons)
  - weathered (C) and fresh (R) rock below the soil profile; and
- any subdivision of the surface, subsurface and subsoil layers that have a major change in texture, colour, rockiness or pH compared with layers above and/or below.

Not every one of these layers is present in each soil profile. In very deep soils, bedrock is not observed within 1 to 2 metres of the natural land surface. Only soils on overland flow paths[2] or floodplain areas will contain buried layers. Subsoil may not be present in very shallow soils where the surface layer may directly overlie bedrock. A subsurface layer is not always present and subsoil may not be present in very shallow soils. At sites that have been severely eroded by overland flow the surface layer may have been removed.

<u>Definition of "topsoil"</u>

The term "topsoil" is avoided when describing and identifying soil features as the term can refer to a wide range of soil materials, such as:

- any material immediately at the land surface;
- all soil layers immediately above a recognised subsoil;
- any material (natural or produced) that is used for topdressing or as planting media; and
- all natural soil layers (or part of) that are suitable for use as planting media.

For the purpose of these SunWater Soil Management Protocols, topsoil will be used to refer any soil material that is suitable for stripping and re-use as planting media. This generally includes both the surface and subsurface layers but, depending on physical and chemical properties, can also include subsoil from all soil management groups except the dispersive texture contrast soils.

In particular, soil material to be stripped as topsoil must not:

- have medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or Cl ≥350 mg/kg where gypsum is present); or
- be strongly dispersive (ESP ≥15 or Ca : Mg ratio ≤.01) in shrink-swell soils (*Shallow medium-heavy clays*, *Deep cracking clays* and *Melonhole clays*); or
- be dispersive (ESP ≥6 or Ca : Mg ratio ≤.01) in all other (rigid) soil management groups;.

Any soil layer that does not fit these specifications for topsoil is referred to as unsuitable soil material. This material will be predominantly subsoil.

4.5 Site features to be described and recorded

<u>Reference sites</u>

Detailed site description is required to establish at least one reference site for each soil management group.

The following site features are to be recorded for each reference site:

- unique identification (e.g. D1);
- location (provided as GPS recorded coordinates);
- position in the landscape (referred to as a "landform element morphological type" in the yellow book);
- surface rock (abundance and size of unconsolidated coarse fragments and abundance of outcropping bedrock);
- gilgai microrelief (type, vertical interval, horizontal interval, component of microrelief sampled);
- slope gradient (in percent slope);
- soil surface condition when dry; and

[2] An overland flow path is defined in the Glossary in Appendix F.

- type of observation, i.e. core, pit, cutting.

The detailed soil profile description should contain for each soil layer:

- upper and lower depth;
- colour of the soil matrix and abundance, size, contrast and colour of any mottles;
- field texture;
- abundance and size of coarse fragments (loose pebbles, cobbles, stones and boulders);
- field pH; and
- boundary distinctness between soil layers.

Check sites

Where only a check site is required to confirm that the site and profile features match a soil management group, the following features should be described:

- unique identification (e.g. C1);
- location (provided as GPS recorded coordinates); and
- all critical soil and site attributes that clearly demonstrates the soil profile belongs to a particular soil management group.

This may involve simply observing ground surface features at a site.

4.6 Identifying which soil management group is represented

Once the landscape and soil features are described, a site can be matched with existing soil descriptions in the Soil Reference.

This matching process is assisted by use of the Soil Key provided in Appendix B.

4.7 Use of the Soil Key

The first step in the key is to determine the position within the landscape for the area being investigated (and thus for the site being described). Soils occurring on alluvial plains that still experience some degree of flooding and on overland flow paths invariably have different soil features to those that are not inundated.

Alluvial plains are usually delineated as Quaternary alluvium (Qa map symbol) on regional geology maps though the accuracy of the Qa boundaries is often poor. The broad, very gently undulating plains that are inundated by concentrated overland flow are not identified separately on regional geology maps. These plains occur mainly north of the Condamine River between Dalby and Warra. They are delineated on the regional land resource mapping by the Department of Natural Resources (Harris et al. 1999) but the accuracy of the boundary locations may be ± 500 m.

Detailed contour information with contour intervals of less than 5 m can also be used to more accurately identify the location of land that is still likely to be inundated. Strip cropping in cultivated land is a management tool designed to minimise the erosive effects of overland sheet flow and its presence will indicate that the area is part of an overland flow path.

Proceeding through the key then depends on the presence of key soil attributes:

- field texture of the surface, subsurface and subsoil layers;
- the boundary change into the subsoil (whether it is sudden, i.e. ≤50 mm, or otherwise);
- structure grade of the subsoil in gradational soils (massive earths or structured earths);

- structure grade and shape and size of individual peds in subsoil of the texture contrast (TC) soils;
- combined thickness of the surface and subsurface layers in TC soils with dispersive clay subsoil;
- presence of surface cracks in soils with a clay surface layer (cracking clays);
- presence of melonhole gilgai on cracking clays; and
- depth to any underlying (fresh or weathered) bedrock.

4.8 Field techniques for recognising dispersive clay subsoil

A prismatic or columnar structure in the clay subsoil almost always indicates a strong tendency for dispersion. The presence of coarse blocky structure (peds of ≥ 50 mm width) is also a good indication of dispersive soil.

However, some clay subsoil with massive to weak structure may also be dispersive.

The presence of a prominent bleach (especially if thick) in the semi-arid environment of the pipeline corridor indicates very limited water movement into the clay subsoil, which is usually associated with the subsoil being dispersive.

With experience, the behaviour of the soil bolus when wetting it for estimating field texture is also a useful indication of dispersive soil material. If the soil bolus becomes slippery like a bar of soap, then it is likely to be sodic and thus dispersive.

A modified version of the aggregate stability laboratory test has also been developed by the New South Wales Department of Agriculture (Hughes 1999). The modified test compares the Clouding and Slaking capacity of small pieces of soil and uses a rating system to indicate any tendency for dispersion. The complete test is best performed in a laboratory as it involves immersing an air dry soil sample in rain water or distilled water and recording slaking after 5 minutes and clouding after 10 minutes and 2 hours respectively. However, a simple 10 minute test can be performed in the field to obtain an indication of likely dispersion.

If there is any doubt at all, the subsoil should be sampled for verification through laboratory analysis.

4.9 Sampling and analysing a soil profile

Particular soil layers should be sampled for laboratory analysis if:

1. the soil can only be tentatively allocated to a soil management group after field description; or
2. field indicators suggest some part of the soil profile may be dispersive, strongly acidic or saline and confirmation is required.

The Soil Mapping Protocol also stipulates that the full soil profile should be sampled for laboratory analysis at a minimum 1% of all sites to establish an adequate baseline dataset for the pipeline corridor (see section 3.5).

<u>Site selection and sampling gear</u>

Sampling and analysis of soil types is best if it follows standard procedures unless there is some particular attribute of that soil which needs special attention. Standardisation of soil sampling facilitates data transfer and comparison and reporting on soil analysis for similar soil types.

A standard sampling procedure used for soil survey was established by McDonald and Baker in 1984 and involves the selection of a representative site that avoids any features that may cause aberrant attributes.

These guidelines apply to general broad area surveys but may have to be modified in smaller areas and for problem solving situations. Detailed guidelines on site selection are provided in section 4.2 above.

Soils can be sampled by the following methods, listed in order of preference:

(a) freshly dug soil pit (highly desirable and to be done as far as financial and time constraints permit);
(a) 38-50 mm core from sampling tube used with hydraulic soil sampling rig;
(b) 50-75 mm hand auger; and
(c) cuttings where available.

Layers to be sampled for characterising a reference site

For laboratory analysis of a full profile at a reference site, samples should be collected at regular intervals down the profile.

Two sampling methods that have been used in Queensland:

1. Samples are taken from set depth increments of 0-100 mm, 200-300 mm, 500-600 mm, 800-900 mm, 1100-1200 mm and 1400-1500 mm, provided these depth increments do not cross a layer boundary.
2. Samples are collected across the entire thickness of every layer up to a maximum 300 mm; if a layer is thicker than 300 mm then it is subdivided into increments of 300 mm (or part thereof) for sampling.

Sampling at set 100 mm depth increments has been used in many soil surveys but these set depths are varied if the increment crosses an important change between soil layers. For example, a set depth increment will have to varied if it:

- crosses the boundary between a subsurface layer and the subsoil of texture contrast soils; or
- entirely misses a relatively thin but important layer.

The most important consideration is that all major layers be sampled.

It is recommended that reference sites for soil management groups be sampled at the following depth increments:

- 0-100 mm
- 200-400 mm
- 400-700 mm
- 700-1,000 mm
- 1,000 mm to bottom of disturbance.

With this sampling technique the following rules are to be applied:

- every major soil layer that has been recognised and described should be sampled; and
- any sample should not cross a layer boundary except where the change is not thought to have notable significance for analysis (for example, a gradual colour change);
- rather, the depth increments should be adjusted to ensure only one layer is represented in each sample.

Laboratory analysis

For comprehensive analysis of reference sites the following laboratory tests should be performed on each depth increment:

- pH, Electrical Conductivity and Chloride on a 1:5 soil : water suspension;

- Exchangeable cations from which Exchangeable Sodium Percentage (ESP) and Exchangeable Calcium : Exchangeable Magnesium (Ca : Mg) ratio can be derived;
- Moisture Content at air dry and at -1500 kPa pressure;
- Particle size distribution; and
- Clouding and Slaking.

In addition, Organic Carbon, Total Nitrogen, Bicarbonate Extractable Phosphorus, Extractable Sulfur and Extractable Micronutrients (Copper, Zinc, Manganese and Iron) should be determined on a composite 0-100 mm surface sample.

Laboratory methods to be used for soil sample assessment are those recommended in an Australian laboratory handbook for soil and water analysis (Rayment and Higginson 1992 and Rayment and Lyons 2010). The methods described are recognized Australia wide as calibrated and consistent methods and procedures that are used for diagnostic and research purposes in Australia. In addition, these methods are those used more or less to produce the background data available for most areas in Queensland.

4.10 Sampling and analysing individual layers

Commonly, individual layers from soil profiles will need to be sampled and analysed if:

- a soil management group can only be tentatively identified using the Soil Key; or
- the dispersion, acidity or salinity of a particular layer needs to be confirmed.

For verifying a tentative soil allocation, the chemical attributes of key layers (usually subsoil) should be compared with existing data for:

- reference sites within the corridor; and/or
- representative profiles published as part of the Central Darling Downs and Western Downs land management manuals (Harris et al. 1999, Maher 1996).

The number of samples and type of laboratory test to be performed will depend on the type of verification required. For example, if there are concerns with subsoil attributes such as acidity and salinity then pH, Electrical Conductivity and Chloride tests on a 1:5 soil : water suspension should be performed.

If there are concerns with dispersion, Exchangeable cations should be analysed, from which ESP and Ca : Mg ratio can be derived. The Clouding and Slaking test can also be undertaken in the laboratory, if required.

5. Risk Assessment and Management Protocol

5.1 Purpose of this protocol

The Risk Assessment and Management Protocol describes the procedure to:

- assess the risk of undertaking particular activities on each soil management group; and then
- select appropriate management strategies to address that risk and minimise the potential impact due to undertaking the activity.

A Soil Risk Matrix is used to match the particular soil management group to be disturbed against each planned activity. For some activities, additional information regarding slope, subsoil salinity and subsoil acidity will also be required to determine the risk rating.

The Soil Risk Matrix refers to a series of Implementation Schedules. Depending on the degree of risk, a particular schedule is selected to determine the appropriate range of management strategies that are required.

5.2 Soil Risk Matrix

The Soil Risk Matrix is provided in Appendix C and compares each soil management group with the range of project activities to be undertaken.

The matrix lists the type of potential impact that a particular activity will create for each soil as well as rating the severity of that impact as either:

- Nil;
- Minor;
- Moderate;
- Severe; or
- Extreme.

The matrix includes 8 activities identified as being part of pipeline construction and operation:

1. clearing and grubbing;
2. stripping and stockpiling topsoil;
3. excavating and stockpiling subsoil;
4. excavating building foundation;
5. excavating trench / inserting pipeline;
6. backfilling and stabilising the trench;
7. forming a maintenance track; and
8. rehabilitating disturbed areas.

5.3 Determination of appropriate management practices

Appropriate management (including mitigation) practices are then determined for the particular type and level of risk by referring to the relevant Implementation Schedules for the soil risk rating.

A key at the bottom of the Soil Risk Matrix refers to the particular Implementation Schedule to be used for each risk rating.

The Implementation Schedules (A to D) are detailed at the end of this document. They list the appropriate management practices that need to be implemented to minimise impact. Within the schedules, the management practices are organised to address the identified soil risk with respect to:

- erosion and sediment control;
- topsoil management;
- subsoil salinity management; and
- subsoil acidity management.

The soil risk associated with management and disturbance to Good Quality Agricultural Land (GQAL) is not addressed within this protocol as SunWater has sought approval for the pipeline to be regarded as an overriding need which will obviate any requirement to protect GQAL from alienation.

The erosion and sediment control practices incorporate and build on best practice measures developed by the International Erosion Control Association, Australasia (Witheridge 2008).

Some management practices refer to recommended topsoil stripping depth and soil amelioration with lime, dolomite or gypsum. The recommended topsoil stripping depth for each soil management group is provided in Appendix D and specifications for lime, dolomite and gypsum soil ameliorants are given in Appendix E.

5.4 Setting benchmarks for a CEMP/OEMP

Though some management practices in the implementation schedules are adopted or implemented during design, many are to be implemented during construction. A few practices also apply to the operational phase of the pipeline project.

All relevant practices will need to be inserted as benchmarks into a CEMP and implemented by a construction contractor. The few practices that refer to operational phase will need to be inserted into an OEMP.

These specific management practices represent a minimum set of strategies to be included in any CEMP or OEMP. The practices may be refined, expanded and added to during preparation of a specific management plan.

6. References and further reading

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Schedule A. Standard management practices for all land

Practice	Description
	General Soil Management
A1	Minimise access and disturbance to only essential areas
A2	Avoid inverting the soil during clearing and grubbing operations
A3	Surround laydown areas with a 0.5 m high soil berm
A4	Rehabilitate disturbed areas as soon as works are completed
A5	When backfilling [1]: - replace and lightly compact [2] the subsoil first - then cap with topsoil and lightly compact [3]
A6	Do not place above-ground infrastructure that will interfere with natural surface flow either within the riparian zone or within overland flow paths [3]
A7	When installing water quality and quantity control structures inside the riparian zone comply with all requirements of the Riverine Protection Permit (and a Waterway Barrier Approval, if required
	Topsoil Management
A8	Carefully strip to recommended stripping depth and stockpile topsoil before starting bulk earthworks
A9	Stripping depth [5] is to be determined by: - soil type where soil depth is not variable (refer to Appendix D) or - by topsoil survey where topsoil depth is described as variable in Appendix D
A10	Material to be stripped for use as topsoil must not: - have medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or Cl ≥350 mg/kg where gypsum is present); or - be strongly dispersive (ESP ≥15 or Ca : Mg ratio ≤.01) in shrink-swell soils (*Shallow medium-heavy clays*, *Deep cracking clays* and *Melonhole clays*); or - be dispersive (ESP ≥6 or Ca : Mg ratio ≤.01) in all other (rigid) soil management groups
A11	Stockpile topsoil and other unsuitable soil material separately; stockpile topsoil to maximum 2 m height
A12	Stockpile batter gradients should be no greater than 33% (1V:3H)
A13	Long-term and permanent stockpiles to be planted with appropriate cover crop
A14	Ensure stockpiles are located outside the riparian zone and not on overland flow paths [3]
	Erosion and Sediment Control
A15	Avoid, where possible, major earthworks programs between November and February
A16	When construction is completed rehabilitate all bare earth areas not covered by hard stand with topsoil and revegetate with appropriate vegetation for the original soil management group that has been disturbed
A17	Cap all long-term (to be retained > 12 months) and permanent stockpiles of unsuitable soil material with at least 100 mm of topsoil
A18	Incorporate check dam and/or sediment trap and/or sediment detention basin into storm water run-off control for all above-ground infrastructure with at least 1,000 square metre of footprint

Notes:

1. Backfilling refers to filling in excavated voids, natural depressions and erosion gullies. Most erosion gullies will be in soils with subsoil that represents unsuitable soil material but a few gullies may be in other soils with no unsuitable soil material. Unsuitable soil material should only be used to backfill erosion gullies where such material is already present.
2. Lightly compacting subsoil refers to soil compaction aimed at attaining 90% maximum dry density. This operation should be done preferably with a sheepsfoot roller that leaves an uneven surface on top of the subsoil and thus thicker pockets of topsoil for plant roots to key into after rehabilitation.
3. Lightly compacting topsoil refers to simply pressing the material down to enhance soil cohesion whilst maintaining a friable seedbed with good soil-seed contact. This operation would be done preferably with machinery such as agricultural press wheels or equivalent.
4. Refer to Glossary in Appendix F for full description of an overland flow path.
5. Stripping depth is the depth from the ground surface to any unsuitable soil material below and usually includes the surface layer and subsurface layer (if present) but may also include subsoil in some soil management groups.

Schedule B. Additional management practices for land with a minor impact rating

Practice	Description
	General Soil Management
B1	Apply practices A1 to A7 listed in Schedule A
	Topsoil Management
B2	Apply practices A8 to A14 listed in Schedule A
B3	Only undertake "topsoil" stripping immediately before starting bulk earthworks OR Install appropriate, temporary run-off control structures immediately after stripping
B4	If on-site stripping to recommended depth as per Appendix D produces insufficient topsoil for rehabilitation: - ameliorate top 100 mm of unsuitable soil material below the surface as per C14 OR - source additional topsoil that is suitable for use as planting media from off-site areas
B5	Test topsoil fertility of soils with a minor "infertile topsoil" risk to check whether fertiliser should be applied when re-spreading at rates as per C3
B6	Test topsoil acidity of soils with a minor "topsoil acidity" risk to check whether amendments should be applied when re-spreading at rates as per C4
B7	Ensure stockpiles are: - constructed on the contour - protected from run-on water with diversion bank or similar device upslope - protected with a berm or catch drain immediately down slope to control run-off
	Erosion and Sediment Control
B8	Apply practices A15 to A18 listed in Schedule A
B9	Level the land surface outside an earthworks footprint immediately after any clearing and grubbing operations are finished; the levelling should create a slight convex shape that spreads run-off water away from the disturbed area rather than allowing it to concentrate
B10	Ensure any holes in a surface to be levelled are filled with topsoil
B11	Lightly compact [1] the levelled surface to ensure it is not easily moved by raindrop splash and running water
B12	Leave the land surface on top of laid pipeline and adjacent service tracks in a slight convex shape that spreads run-off water away from the pipeline or track rather than allowing it to concentrate
B13	At above-ground infrastructure sites with at least 1,000 square metre of footprint protect the hardstand area with appropriate drainage control, erosion control and sediment control measures listed in IECA Best Practice Erosion and Sediment Control [2]
B14	Design sediment trap or sediment detention basin at end of diversion drains to specification for: - dispersive material on all *dispersive texture contrast soils* and on *Melonhole clays* - coarse material on *Shallow sands and loams*, *Deep sands and sandy loams* or on "sandy" *Massive earths* - fine material on all other soils
	Subsoil Salinity Management
B15	For saline profiles of *Deep cracking clays* and *Melonhole clays*: Regard any soil layer with medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or Cl ≥350 mg/kg where gypsum is present) as unsuitable soil material and - cap with suitable topsoil to a thickness matching the pre-disturbance topsoil depth

Notes:

1. Lightly compacting the surface refers to simply pressing the material down to enhance soil cohesion whilst maintaining a friable seedbed with good soil-seed contact. This operation would be done preferably with machinery such as agricultural press wheels or equivalent.

2. Reference is Witheridge G (2008), Best Practice Erosion and Sediment Control – for building and construction sites, IECA Australasia.

Schedule C. Special management practices for land with a moderate to severe impact rating

Practice	Description
	General Soil Management
C1	Apply practices A1 to A7 listed in Schedule A
	Topsoil Management
C2	Apply practices B2 to B7 listed in Schedule B
C3	Apply fertiliser mix to topsoil when re-spreading at the following rates: - 200 to 250 kg/ha NPK fertiliser, such as Sierra Blen Turfstarter (NPK 16:10:10), for topsoil from *Cracking clays* and *Melonhole clays* - 350 kg/ha NPK fertiliser, such as Sierra Blen Turfstarter (NPK 16:10:10), for all other topsoil CRF (coated) fertiliser is recommended especially in riparian zones or equivalent
C4	Ameliorate topsoil with a moderate "topsoil acidity" risk before re-use with dolomite or lime to a specification as per Appendix E at the following rate: - 1.5 kg/m^3 (or 0.15 kg/m^2 per 100 mm depth) This is best achieved by spreading dolomite or lime prior to stripping
	Erosion and Sediment Control
C5	Apply practices B8 to B14 listed in Schedule B
C6	Where backfilling [1] or spreading with unsuitable soil material, the unsuitable soil material should: - be lightly compacted [2] - be capped with suitable topsoil to a thickness matching the pre-disturbance topsoil depth OR - have at least the top 100 mm of unsuitable soil material ameliorated if there is insufficient topsoil available AND - be seeded with appropriate plant species Unsuitable soil material that is dispersive (ESP ≥6 or Ca : Mg ratio ≤.01) can be ameliorated by: - applying 15 kg/m^3 (or 15 t/ha per 100 mm thickness) of dolomite or lime to a specification as per Appendix I
C7	Incorporate run-off control devices to reduce slope length on access tracks and the pipeline in accordance with appropriate measures listed in IECA Best Practice Erosion and Sediment Control [3]. In particular: - permanent devices are to be installed at areas where vegetation cover will not re-establish within 12 months - though temporary devices can be used at areas where cover will re-establish within 12 months
C8	Avoid placing above-ground infrastructure within overland flow paths [4] and grassed waterways
C9	If used, protect borrow pits during construction, operation and following decommission by building a diversion bank and/or diversion drain on the upslope side
C10	Leave final cut faces on borrow pits as close to vertical as possible (to minimise erosion due to raindrop splash)
	Subsoil Salinity Management
C11	Apply practice B15 listed in Schedule B
C12	Where backfilling or spreading with subsoil of medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or CL ≥ 350 mg/kg where gypsum is present): - lightly compact [2] backfill [1]; and - then cap with suitable topsoil to a thickness matching the pre-disturbance topsoil depth

Practice	Description
C13	Protect borrow pits during construction, operation and following decommission by: - building a perimeter berm around any pit that exposes subsoil with medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or CL ≥ 350 mg/kg where gypsum is present)
	Subsoil Acidity Management
C14	Where backfilling [1] or spreading with subsoil of very strong to extreme acidity (pH ≤5), the acid subsoil should be: - lightly compacted [2] ; and - the top 100 mm should be ameliorated as soon as possible with 1.5 kg/m^3 (or 1.5 t/ha) of dolomite or lime to a specification as per Appendix E; - then capped with suitable topsoil to a thickness matching the pre-disturbance topsoil depth
C15	Protect borrow pits during construction, operation and following decommission by: - building a perimeter berm around any pit that exposes subsoil with very strong to extreme acidity (pH ≤5)

Notes:

1. Backfilling refers to filling in excavated voids, natural depressions and erosion gullies. Most erosion gullies will be in soils with subsoil that represents unsuitable soil material but a few gullies may be in other soils with no unsuitable soil material. Unsuitable soil material should only be used to backfill erosion gullies where such material is already present.
2. Lightly compacting unsuitable soil material being used as backfill refers to soil compaction aimed at attaining 90% maximum dry density. This should be done preferably with a sheepsfoot roller that leaves an uneven surface on top of the subsoil and thus thicker pockets of topsoil for plant roots to key into after rehabilitation.
3. Reference is Witheridge G (2008), Best Practice Erosion and Sediment Control – for building and construction sites, IECA Australasia.
4. Refer to Glossary in Appendix F for full description.
5. Unsuitable soil material with medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or CL ≥ 350 mg/kg where gypsum is present) cannot be ameliorated.

Schedule D. Special management practices for land with an extreme impact rating

Practice	Description
D1	Avoid disturbance and seek an alternative site or route or if an alternative site/route is not available: - special management and mitigation practices need to be designed for each location with extreme risk rating - seek specialist advice from an independent land management expert for design of specialist practices prior to any disturbance
D2	If disturbance must be undertaken, apply all relevant practices listed in Schedules A, B and C as well as recommended strategies from the land management expert

Appendix A. Soil management groups for the Surat and Bowen Basins

(Originally prepared by LRAM for DEHP and adapted from its draft guideline for beneficial use approval of irrigating treated CSG water being prepared by DEHP.)

Shallow sands and loams [3]

Concept

This group contains shallow soils on uplands that overlie bedrock at < 1 m and have either a uniform, coarse textured profile or a uniform, medium textured profile. Many profiles also contain loose fragments of gravel, cobbles, stones and boulders and solid bedrock may outcrop at the surface.

Characteristic features

Texture grade may vary:

- between sand, loamy sand, clayey sand and sandy loam for coarse textured profiles; or
- between loam, silty loam and sandy clay loam for loamy textured profiles.

Profiles with mainly sand and loamy sand generally remain as a single grained structure; sandy loams tend to be coherent with a massive structure and loams and silty loams have mainly a massive to weak structure. Sand, loamy sand, clayey sand textures have a loose to very weak consistence; sandy loam, loam and silty loam generally exhibit a weak to firm consistence. The surface condition when dry is loose to firm for the coarse textured profiles but firm to hard setting for the loamy profiles.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are uplands varying from gently undulating rises to hills which are derived from mainly sedimentary rocks, acid to intermediate volcanics, metamorphic rocks and on lateritic scarps.

Shallow clay loams and light clays

Concept

This unit contains shallow soils on uplands that overlie bedrock at < 1 m and have either uniform, medium textured profiles or uniform, fine textured (clay) profiles of light clay to light medium clay texture. Many profiles also contain loose fragments of gravel, cobbles, stones and boulders and solid bedrock may also outcrop at the surface.

Characteristic features

Texture grade may vary:

- between sandy clay loam, clay loam, silty clay loam and clay loam, sandy for medium textured profiles; or
- between light clay and light medium clay for fine textured profiles.

Structure is mainly moderate to strong but can be weak and occasionally massive. Where present, the individual peds are mainly fine-sized (maximum width ≤20 mm) but subsoil peds in the fine textured profiles may be of medium size (maximum width 20 to 50 mm). The profiles are friable (easily dug and worked with machinery when moist).

Shallow structured earths with texture gradually increasing with depth from a loam to clay loam surface but with otherwise identical soil features are included with the *Shallow clay loams and clays*.

[3] The term shallow is used to indicate a soil which overlies bedrock (either hard or softer, weathered rock) or continuous gravel layer at less than 1 m depth below the natural land surface.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are uplands varying from gently undulating rises to hills and mountains which are derived from mainly fine-grained sedimentary rocks, basalt and similar basic to intermediate volcanics.

Shallow medium-heavy clays

Concept

This unit contains shallow soils on uplands that overlie bedrock at < 1 m and have uniform, fine textured (clay) profiles with medium to heavy clay texture below the surface layer. Many profiles also contain loose fragments of gravel, cobbles, stones and boulders and solid bedrock may also outcrop at the surface.

Many of these clay profiles exhibit a capacity to shrink as they dry and swell during wetting. The drying cycle forms cracks extending vertically down the profile from near the soil surface and thus these soils are often referred to as “cracking clays”.

However, some profiles with almost identical soil features do not shrink and swell with changing moisture content and are often described as “non-cracking clays”. In fact, if a soil profile is wet during field inspection cracking clays may be easily mistaken for non-cracking clays. Conversely, non-cracking clays may be wrongly classified as cracking clays during wet field conditions on the mistaken assumption that the soil will crack as it dries. Therefore, the non-cracking clays and cracking clays have been placed into this one soil unit.

Characteristic features

Texture grade may vary between light clay to light medium clay at the surface but is slightly heavier (medium clay to heavy clay) below.

Structure is mainly moderate to strong and the individual peds are fine to medium- sized in the surface layer though the subsoil peds can vary in size. Subsoil in some profiles is finely structured but peds can also be of medium to coarse (maximum width ≥50 mm) size. The heavier clay content and large ped size in the coarser structured profiles makes these profiles harder and more intractable than the *Shallow clay loams and light clays*. Profiles with finely structured subsoil tend to be friable.

Many profiles develop vertical cracks at or just below the surface as they dry, often referred to as “cracking clays”, but some also represent “non-cracking clays”. The soils have a strong, very strong or rigid consistence below the surface layer and the condition of the surface is often self-mulching but may be firm to hard setting.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are uplands varying from gently undulating rises to hills and mountains which are derived from mainly fine-grained sedimentary rocks, basalt and similar basic to intermediate volcanics.

Deep sands and sandy loams [4]

Concept

This group contains deep soils with a uniform, coarse textured profile that occur on gently undulating uplands and on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow.

[4] The term deep is used to indicate a soil which overlies bedrock (either hard or softer, weathered rock) or continuous gravel layer at ≥ 1 m depth below the natural land surface.

Characteristic features

Texture grade may vary between sand, loamy sand, clayey sand and sandy loam. Profiles with mainly sand and loamy sand generally remain as a single grained structure whereas the sandy loams tend to be coherent with a massive structure. Sand, loamy sand, clayey sand textures have a loose to very weak consistence whereas sandy loam generally exhibits a weak to firm consistence. The surface has a loose to firm condition when dry. Soil profile depth is at least 1 m.

On lowlands subject to flooding the soil profiles are often stratified with buried layers of different deposition being clearly evident down the profile. The buried layers may have much different texture but such soils are identified and classified according to the most recent layers between the surface and the first buried layer encountered.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are:

- lower slopes of hills and mountains derived from sandstone and similar rocks;
- gently undulating uplands on unconsolidated sediments; and
- stream levees, channel benches and relict stream channels of the alluvial plains.

Deep loams and clay loams

Concept

This group contains deep soils with uniform, medium textured profiles occurring on level to very gently undulating lowlands which are subject to occasional stream flooding and concentrated overland flow. The profiles are often stratified with buried layers of different deposition being clearly evident down the profile.

Characteristic features

Texture grade may vary between loam, silty loam, sandy clay loam, clay loam, silty clay loam and clay loam, sandy. Buried layers may have much different texture but the soils are identified and classified according to the most recent layers between the surface and the first buried layer encountered. Structure can vary from massive through weak to strong. Soils with stronger structure also tend to have a higher fertility. Loams and clay loams generally exhibit a weak to firm consistence. The condition of the surface varies from firm to hard setting when dry. Soil profile depth is at least 1 m.

This is only a minor soil group within the Surat and Bowen Basins, typically occurring on stream levees, lower lying terraces and channel benches of the flood plains.

Structured earths

Concept

This group contains deep soils occurring mainly on undulating uplands. They have gradational texture profiles in which the loam to clay loam surface texture gradually increases with depth and structure is moderate to strong in the subsoil.

Characteristic features

Texture grade in the surface layer may be loam, silty loam, sandy clay loam, clay loam, silty clay loam and clay loam, sandy but reach medium clay deep in the subsoil. Structure may vary from weak to strong in the surface layer but is invariably moderate to strong below. Individual peds are predominantly fine-sized though subsoil peds may be of medium size. Consistence varies with clay content. The condition of the dry surface varies from firm to hard setting. Soil colour is usually black to brown but red profiles may also occur. Soil profile depth is at least 1 m.

Uniform, fine textured profiles ("non-cracking clays") with identical soil features except for a slightly heavier (light clay to light medium clay) surface texture are included with the *Structured earths*.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are rises and hills developed on basalt, similar basic to intermediate volcanic and fine-grained sedimentary rocks. The uplands between Toowoomba and Jondaryan contain significant areas of this soil group. Small areas are also present on stream levees and lower lying terraces of the flood plains. In such situations, the profiles may be stratified with buried layers of different deposition being clearly evident below the structured earths.

Deep cracking clays

Concept

This group of deep soils consists of uniform, fine textured profiles that are coarsely structured at depth. They occur on undulating uplands and on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow.

Most profiles exhibit a capacity to shrink as they dry and swell during wetting, forming vertical cracks down the profile. Though "non-cracking clays" with almost identical soil profile features also occur and are included in this soil unit, the unit is referred to as *Deep cracking clays* as the largest area of these soils do crack.

Characteristic features

Texture grade is generally light medium clay to heavy clay although light clay textures may occur at the surface. Soil structure is generally moderate to strong but the coarse soil peds (at depth result in slow to very slow permeability. The surface condition changes from a sealed, massive appearance when wet, often changing through a thin flake with fine polygonal cracks as it dries, to be either self-mulching, crusting or hard setting when completely dry. The hard setting surface merges into the soil below and may be massive with no observable aggregates but usually contains a few, coarse, hard aggregates within it. Light clays tend to have firm to very firm consistence; medium to heavy clays generally have a strong, very strong or rigid consistence. Soil colour is mainly black, grey or brown and pH may vary from very strongly acid to strongly alkaline at the bottom of the profile. Soil profile depth is at least 1 m.

Normal or linear gilgai microrelief are present on many cracking clay profiles but are not a common feature of the non-cracking clay profiles.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are:

- gently undulating plains and rises on basalt or on fine-grained sedimentary rocks (claystone and siltstone) such as the rolling downs;
- gently undulating plains on unconsolidated sediments that have been eroded from these rocks and which are commonly associated with brigalow scrub; and
- flats and lower-lying backplain areas of the alluvial plains and broad, very gently sloping plains which are occasionally inundated by overland sheet flow and this is a prominent soil group on the major river flood plains.

Very small areas of non-cracking clays also occur on saline mud flats associated with inland salt lakes.

Melonhole clays

Concept

This group contains deep soils on very gently undulating uplands with a uniform, fine textured profile that exhibits a capacity to shrink as they dry and swell during wetting and have melonhole gilgai microrelief.

Characteristic features

Profile features are identical to the *Deep cracking clays* except:

- melonhole gilgai microrelief is present with a vertical interval of at least 300 mm between the bottom of the depressions and the top of the mounds;
- some mound profiles may be coarsely structured, non-cracking clays but the depression profiles are invariably cracking clays; and
- subsoil colour is predominantly grey but may become brown with increasing depth.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are gently undulating plains formed on unconsolidated sediments which have eroded from deeply weathered sedimentary rocks. Minor areas also directly overlie fine-grained sedimentary rocks.

Massive earths

Concept

This group contains soils with shallow to deep profiles in which the surface texture is sandy or loamy and then gradually increases with depth though structure remains massive in the subsoil. Some shallow profiles also contain loose fragments of gravel, cobbles, stones and boulders and solid bedrock may also outcrop at the surface.

Characteristic features

For the sandy massive earths, texture grade in the surface layer may vary between sand, loamy sand, clayey sand and sandy loam and reach sandy clay loam to (sandy) light clay deep in the subsoil. For the loamy massive earths, texture grade in the surface layer may be loam, silty loam or sandy clay loam in the surface layer and may reach light medium clay deep in the subsoil.

The coarser textured surface layers (sand, clayey sand and loamy sand) generally have a single grained structure whereas the heavier sandy loam to sandy clay loam surface is usually massive. As clay content increases below the surface structure becomes massive. Consistence varies with clay content. The surface condition when dry is loose to firm for the sandy massive earths but firm to hard setting for the loamy massive earths. Soil colour is mainly red or yellow and pH is generally acid to neutral.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are mainly deeply weathered (such as ferricrete) with little evidence of the original rock fabric, where:

- shallow profiles dominate the dissected tablelands and jump-ups; and
- deep profiles occur on tablelands, undulating plains and rises.

Massive earths also occur to a lesser extent on gently undulating to hilly uplands developed on other sedimentary rocks and on stream levees, terraces and alluvial plains on the lowlands.

Non-dispersive TC soils

Concept

This group occurs on uplands and on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow. The soils have shallow to deep texture contrast (TC) profiles with surface and subsurface layers suddenly changing (over ≤50 mm thickness) into non-dispersive clay subsoil.

Characteristic features

Texture grade in the surface and subsurface layers may vary from sandy loam to sandy clay loam. A subsurface layer is not always present, especially in soils with red coloured subsoil, but is often present as a sporadic bleached layer in soils. The brown and grey coloured subsoil may vary in texture grade from light clay to heavy clay. Structure in the subsoil varies from weak to strong but the size of individual peds is fine to coarse (10 to ≥50 mm maximum width). The dry condition of the surface varies with clay content from firm to hard setting. The clay subsoil has a typically very firm to strong consistence when dry but is generally friable (easily tilled by mechanical means) when moderately moist.

Typical landscapes

This group occupies relatively small areas within the Surat and Bowen Basins, typically on:

- gently undulating plains to undulating rises developed on sedimentary rocks (some deeply weathered) and basalt;
- hills and plateau surfaces of dissected tablelands on deeply weathered sedimentary rocks; and
- stream levees and terraces on lowlands.

The small areas of granitic rocks that occur within the basins may also contain this group.

Thin-surfaced, dispersive TC soils

Concept

This group occurs on uplands and on level to very gently undulating lowlands subject to occasional stream flooding and concentrated overland flow. The shallow to deep texture contrast (TC) soils have thin surface and subsurface layers suddenly changing (over ≤50 mm thickness) into dispersive clay subsoil.

Characteristic features

Texture grade in the surface and subsurface layers may vary from loamy sand to sandy clay loam and clay loam. A conspicuously or sporadically bleached subsurface layer is usually present. Subsoil colour is quite variable ranging from mottled grey, yellow and brown on the uplands to mainly grey, black and brown or combinations of these colours on the lowlands. Red subsoil can also occur on the uplands and on levees within the lowlands. The subsoil may vary in texture grade from light clay to heavy clay. Total thickness of the combined surface and subsurface layers is ≤200 mm. Structure in the subsoil usually varies from weak to strong but may be massive. The size of individual peds is at least medium (≥20 mm width) and often coarse (≥50 mm width). The dry condition of the surface varies with clay content from soft to hard setting. The clay subsoil has a typically strong to rigid consistence when dry and is hard and intractable unless quite wet.

On lowlands subject to flooding, the soil profiles are often stratified with buried layers of much different texture being present.

Typical landscapes

This is a prominent soil group on all landscapes with ironbark and box woodlands within the Surat and Bowen Basins, including:

- hills, dissected tablelands and undulating rises and plains on the uplands;
- gently undulating plains on unconsolidated sediments that have been eroded from these rocks; and
- narrow valley flats and broad, level alluvial plains on the lowlands.

Thin-surfaced, dispersive TC soils are also often associated with *Deep cracking clays* on the gently undulating plains that once supported brigalow scrub. When cultivated, the profiles will generally become non-cracking clays have a hard setting or crusting surface.

Thick-surfaced, dispersive TC soils

Concept

This group contains shallow to deep soils that have texture contrast (TC) profiles with thick surface and subsurface layers suddenly changing into dispersive clay subsoil.

Characteristic features

Profile features are identical to the *Thin-surfaced, dispersive TC soils* except:

- texture grade in the surface and subsurface layers may vary from sand to clay loam; and
- total thickness of the combined surface and subsurface layers is >200 mm.

Typical landscapes

Typical landscapes within the Surat and Bowen Basins for this group are:

- hills, dissected tablelands and undulating rises and plains on the uplands;
- gently undulating plains on unconsolidated sediments that have been eroded from these rocks; and
- narrow valley flats and broad, level alluvial plains on the lowlands.

Appendix B. Key to soil management groups

Step	Soil Feature	Decision
1	Soil is located on level to gently undulating plains, with occasional gravel on the surface (soil profile usually ≥1 m)	Go to Step 2
	Soil is located on elevated, often rocky, terrain - rises, ridgelines, hills, jump-ups, scarps and dissected tablelands (soil profile usually <1 m)	Go to Step 11
2	Field texture [1] is quite uniform and is either "sandy", "loam to clay loam" or clay throughout profile; buried layers of former deposition may be evident	Go to Step 3
	Field texture [1] gradually increases with depth below a "sandy" or "loam to clay loam" surface; buried layers of former deposition may be evident	Go to Step 8
	Field texture [1] suddenly changes from "sandy" or "loam or clay loam" near the surface to clay subsoil; buried layers of former deposition may be evident	Go to Step 9
3	Field texture [1] of the surface layer is not clay	Go to Step 4
	Field texture [1] of the surface layer is clay	Go to Step 5
4	Field texture grade throughout profile may vary from sand, loamy sand, clayey sand to sandy loam (except for some buried layers)	*Deep sands and sandy loams*
	Field texture grade throughout profile may vary from loam, silty loam, sandy clay loam, silty clay loam to clay loam, sandy (except for some buried layers)	*Deep loams and clay loams*
5	When dry, vertical cracks form at or just below the surface or the surface layer is self-mulching	Go to Step 6
	When dry, no vertical cracks form at or just below the surface and the surface layer is not self-mulching	Go to Step 7
6	Melonhole gilgai (irregular depressions and mounds with at least 300 mm vertical interval) dominate the ground surface	*Melonhole clays*
	Melonhole gilgai are not present or do not dominate the ground surface	*Deep cracking clays*
7	Non-cracking clays with moderate to strong structure below the surface layer and fine-sized peds (maximum width ≤20 mm)	*Structured earths* [2]
	Non-cracking clays with moderate to strong structure below the surface layer and medium to coarse peds (maximum width >20 mm)	*Deep cracking clays* [3]
8	Structure below the surface layer is massive to weak (few, if any, peds are evident)	*Massive earths*
	Structure below the surface is moderate to strong (at least ⅓ of the material consists of peds)	*Structured earths*
9	Texture contrast soils with dispersive clay subsoil (usually consists of prismatic, columnar or coarse blocky peds, ≥50 mm width)	Go to Step 10

Step	Soil Feature	Decision
	Texture contrast soils with non-dispersive clay subsoil (usually massive structure or consists of fine to medium-sized blocky peds, <50 mm width)	*Non-dispersive TC soils*
10	Thickness of the surface layer and any subsurface layers above the clay subsoil is ≤200 mm	*Thin-surfaced, dispersive TC soils*
	Thickness of the surface layer and any subsurface layers above the clay subsoil is >200 mm	*Thick-surfaced, dispersive TC soils*
11	Field texture [1] is quite uniform throughout profile; texture may be "sandy" or vary from loam, silty loam to sandy clay loam	*Shallow sands and loams*
	Field texture [1] is quite uniform throughout profile; texture grade may vary from clay loam, silty clay loam to clay loam, sandy	*Shallow clay loams and light clays*
	Field texture [1] is quite uniform throughout profile; texture grade is light clay in the surface layer and light clay to light medium clay below; friable soils with no vertical cracks form when dry	*Shallow clay loams and light clays*
	Field texture [1] is quite uniform throughout profile; texture is light clay to heavy clay at the surface and medium clay to heavy clay below; vertical cracks may form when dry	*Shallow medium-heavy clays*
	Field texture [1] gradually increases with depth below a "sandy" or "loam to clay loam" surface; structure below the surface layer is massive to weak	*Massive earths*
	Field texture [1] gradually increases with depth below a "loam to clay loam" surface; structure below the surface layer is moderate to strong	*Shallow clay loams and light clays* [4]
	Field texture [1] suddenly changes from "sandy" or "loamy or clay loam" near the surface to clay subsoil	Go to Step 9

Notes:

1. Field texture:

   "sandy" refers to texture grades of sand; loamy sand; clayey sand; sandy loam

   "loam to clay loam" refers to texture grades of loam; silty loam; sandy clay loam; clay loam; clay loam, sandy; silty clay loam

   clay refers to texture grades of light clay; light medium clay; medium clay; medium heavy clay; heavy clay
2. Non-cracking clays with fine-sized peds have similar attributes to *Structured earths* and are included with these soils.
3. Non-cracking clays with coarse ped size have similar attributes to *Deep cracking clays* and are included with these soils.
4. Technically, these soils represent shallow structured earths but have similar attributes to *Shallow clay loams and light clays* and are included with this latter group.

Appendix C. Soil Risk Matrix

Activity	Soil management group					
	Shallow sands and loams	Shallow clay loams and light clays	Shallow medium-heavy clays	Deep sands and sandy loams	Deep loams and clay loams	Structured earths
Clearing and grubbing	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope)	erosion (1-3% slope)	erosion (1-3% slope) erosion (>3% slope)
Strip and stockpile topsoil	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope) subsoil salinity (if very high - extreme)	erosion (1-3% slope)	erosion (1-3% slope)	erosion (1-3% slope) erosion (>3% slope)
Excavate pipeline trench	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope)	erosion (1-3% slope)	erosion (1-3% slope) erosion (>3% slope)
Excavate building foundations	erosion (1-3% slope) erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (1-3% slope)	erosion (1-3% slope)	erosion (1-3% slope) erosion (>3% slope)
Stockpile subsoil material	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope) subsoil salinity (if very high - extreme) subsoil acidity (if pH ≤5)	erosion (1-3% slope)	erosion (1-3% slope)	erosion (1-3% slope) erosion (>3% slope)
Form service track	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope) erosion (3-10% slope) erosion (>10% slope)	erosion (1-3% slope)	erosion (1-3% slope)	erosion (1-3% slope) erosion (>3% slope)
Reform and stabilise trenches	insufficient topsoil infertile topsoil topsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil topsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	infertile topsoil	erosion (1-3% slope)	topsoil acidity (if pH ≤5)
Rehabilitate other disturbed areas	insufficient topsoil infertile topsoil topsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil topsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	infertile topsoil	erosion (1-3% slope)	topsoil acidity (if pH ≤5)

Impact rating	Appropriate Management Practise
Nil	Refer to Schedule A of Soil Management Plan
Minor	Refer to Schedule B of Soil Management Plan
Moderate	Refer to Schedule C of Soil Management Plan
Severe	Refer to Schedule C of Soil Management Plan
Extreme	Refer to Schedule D of Soil Management Plan

Slope measurement for erosion hazard
Slope is measured in the direction of maximum change across the overal landscape surface.

Activity	Soil management group					
	Deep cracking clays	Melonhole clays	Massive earths	Non-dispersive TC soils	Thin-surfaced, dispersive TC soils	Thick-surfaced, dispersive TC soils
Clearing and grubbing	erosion (1-3% slope) erosion (>3% slope)	erosion (>1% slope)	Sandy massive earths: erosion (1-3% slope) Sandy massive earths: erosion (>3% slope) Loamy massive earths: erosion (1-3% slope) Loamy massive earths: erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (≤1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)	erosion (<1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)
Strip and stockpile topsoil	erosion (1-3% slope) erosion (>3% slope) subsoil salinity (if very high - extreme)	erosion (>1% slope)	Sandy massive earths: erosion (1-3% slope) Sandy massive earths: erosion (>3% slope) Loamy massive earths: erosion (1-3% slope) Loamy massive earths: erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (≤1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)	erosion (<1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)
Excavate pipeline trench	erosion (1-3% slope) erosion (>3% slope)	erosion (>1% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (≤1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)	erosion (<1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)
Excavate building foundations	erosion (1-3% slope) erosion (>3% slope)	erosion (>1% slope)	Sandy massive earths: erosion (1-3% slope) Sandy massive earths: erosion (>3% slope) Loamy massive earths: erosion (1-3% slope) Loamy massive earths: erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (≤1% slope) erosion (1-3% slope) erosion (>3% slope)	erosion (<1% slope) erosion (1-3% slope) erosion (>3% slope)
Stockpile subsoil material	erosion (1-3% slope) erosion (>3% slope) subsoil salinity (if very high - extreme) subsoil acidity (if pH ≤5)	erosion (>1% slope) subsoil salinity (if very high - extreme) subsoil acidity (if pH ≤5)	Sandy massive earths: erosion (1-3% slope) Sandy massive earths: erosion (>3% slope) Loamy massive earths: erosion (1-3% slope) Loamy massive earths: erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope) subsoil acidity (if pH ≤5)	erosion (≤1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%) subsoil salinity (if very high - extreme) subsoil acidity (if pH ≤5)	erosion (<1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%) subsoil salinity (if very high - extreme) subsoil acidity (if pH ≤5)
Form service track	erosion (1-3% slope) erosion (>3% slope)	erosion (>1% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (1-3% slope) erosion (>3% slope)	erosion (≤1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)	erosion (<1% slope) erosion (1-3% slope) erosion (3-8% slope) erosion (>8%)
Reform and stabilise trenches	insufficient topsoil infertile topsoil subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	infertile topsoil topsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil subsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil topsoil acidity (if pH ≤5) subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	infertile topsoil topsoil acidity (if pH ≤5) subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)
Rehabilitate other disturbed areas	insufficient topsoil infertile topsoil subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	infertile topsoil topsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil subsoil acidity (if pH ≤5)	insufficient topsoil infertile topsoil topsoil acidity (if pH ≤5) subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)	infertile topsoil topsoil acidity (if pH ≤5) subsoil salinity (if medium or higher) subsoil acidity (if pH ≤5)

Slope measurement for erosion hazard	Impact rating	Appropriate Management Practise
Slope is measured in the direction of maximum change across the overal landscape surface.	Nil	Refer to Schedule A of Soil Management Plan
	Minor	Refer to Schedule B of Soil Management Plan
	Moderate	Refer to Schedule C of Soil Management Plan
	Severe	Refer to Schedule C of Soil Management Plan
	Extreme	Refer to Schedule D of Soil Management Plan

Appendix D. Topsoil stripping depth for the soil management groups

Topsoil refers to any soil material on-site that is suitable for stripping and re-use as planting media.

Soil management group	Maximum stripping depth [1](mm) Earth works footprint
Shallow sands and loams	100
Shallow clay loams and clays	100
Shallow medium-heavy clays	200
Deep sands and sandy loams	200
Deep loams and clay loams	200
Deep cracking clays	Variable [2, 3] (maximum 300 mm)
Melonhole clays	200 [4]
Massive earths	300
Structured earths	200
Non-dispersive TC soils	Variable [2] (maximum 400 mm)
Thin-surfaced, dispersive TC soils	Variable [2] (maximum 200 mm)
Thick-surfaced, dispersive TC soils	200

Notes:

1. The recommended maximum stripping depth includes suitable soil material from the surface layer, from the underlying subsurface layer (if present) and from subsoil. It specifically excludes unsuitable soil material, which is any soil layer that:
   - is strongly dispersive (ESP ≥15 or Ca : Mg ratio ≤.01) in shrink-swell soils (*Shallow medium-heavy clays*, *Deep cracking clays* and *Melonhole clays*); or
   - is dispersive (ESP ≥6 or Ca : Mg ratio ≤.01) in all other (rigid) soil management groups; or
   - has medium or higher salinity ($EC_{1:5}$ ≥0.24 dS/m, or CL ≥ 350 mg/kg where gypsum is present).
2. "Variable" stripping depth needs to be tested by topsoil survey prior to stripping.
3. Thickness of suitable topsoil in *Deep cracking clays* will depend upon the salinity, pH and capacity for dispersion of underlying soil material.
4. A 200 mm topsoil stripping depth for the *Melonhole clays* should result in only material from the mounds being stockpiled for topsoil as the vertical interval between the tops of the mounds and bottom of the depressions is at least 300 mm. $EC_{1:5}$, Cl, pH, ESP and Ca : Mg ratio for the 0-200 mm layer of the mounds should be generally within the target levels set for topsoil rehabilitation (see Schedule C).

Appendix E. Specification requirements for soil ameliorants

Material requirements

The soil amelioration agents (lime, gypsum and dolomite) used for the SunWater pipeline project shall comply with the requirements stated below.

Lime and Dolomite

Lime shall be agricultural lime consisting of natural ground limestone (calcium carbonate - $CaCO_3$).

Dolomite shall be agricultural dolomite ($CaMgCO_3$).

Lime and dolomite shall meet the following parameter requirements:

- have a neutralising value (NV) of 90 and above determined by using the test method 19A1 from the Australian Laboratory Handbook of Soil and Water Chemical Methods (1992) by Rayment and Higginson or Rayment and Lyons (2010);
- have a pH value of 8.5 +/- 0.5 determined by using the test method identified in Clause 5.5 of AS 4419 – *Soils for landscaping and garden use*
- have a particle size (fineness) of:
    - 100% by weight to pass a 5 mm sieve
    - 95% by weight to pass a 3.5 mm sieve
    - 40% by weight to pass a 0.15 mm sieve

Gypsum

Gypsum (calcium sulfate $CaSO_4 2H_2O$) shall be a natural agricultural grade material.

Gypsum shall meet the following parameter requirements:

- a minimum 80% of gypsum
- a moisture content of <15%
- have a total content (x-ray fluorescence test) of:
    - > 20% calcium (Ca)
    - > 15% sulphur (S)
    - < 2% sodium chloride (NaCl)
- if manufactured - have a total content of heavy metals:
    - < 0.001% cadmium (Cd)
    - < 0.01% lead (Pb)
- have a particle size distribution of:
    - 100% by weight to pass a 6 mm sieve
    - 80% by weight to pass a 4 mm sieve
    - 50% by weight to pass a 2 mm sieve

Appendix F. Glossary of technical terms

Acidity	The chemical activity of hydrogen ions in soil expressed in terms of pH .... see also **pH**
Acid soil	A soil giving an acid reaction throughout most or all of the soil profile (below a pH of 6.5); generally speaking, acid soils become a problem when the pH drops below 5.5 .... see also **pH**
Alkaline soil	A soil giving an alkaline reaction throughout most or all of the soil profile (pH higher than 7.4)
Alluvial plain	A level landform with extremely low relief formed by the accumulation of alluvium from overbank stream flow over a considerable period of time; this accumulation may still be occurring (flood plain) or may have ceased (terrace)
Alluvium	Deposits of gravel, sand, silt, clay or other debris, moved by streams from higher to lower ground
Backplain	A large flat on a flood plain at some distance from the stream channel and aggraded by stream flooding
Base saturation	A ratio relating the major nutrient cations (calcium, magnesium, sodium and potassium) to the CEC
Buffer capacity	The ability of a soil to resist changes in pH due to the properties of clay and fine organic matter; thus, with the same pH level, more lime is required to neutralise a clayey soil than a sandy soil
Channel bench	A flat at the margin of a stream channel that continues to be aggraded and eroded by stream flooding; often described as a “low terrace” in Queensland
Clay loams	Soils with a uniform "clay loam" texture clay loam, silty clay loam and/or clay loam, sandy throughout the soil profile
Clay	A soil separate consisting of particles less than 0.002 mm in equivalent diameter
Clays	Soils with a uniform light clay to heavy clay texture throughout the soil profile
.... cracking	Clay soils that develop vertical cracks near the surface when dry
.... non-cracking	Clay soils that do not develop vertical cracks near the surface when dry
Coarse grained sedimentary rocks	see **Sedimentary rocks .... coarse grained**
Consistence	Consistence refers to the strength of cohesion and adhesion in soil; strength is determined by the force just sufficient to break or deform a 20 mm diameter piece of soil when a compressive shearing force is applied between thumb and forefinger

.... loose	No force required
.... very weak	Very small force, almost nil
.... weak	Small but significant force
.... firm	Moderate or firm force
.... very firm	Strong force but within the power of thumb and forefinger
.... strong	Beyond power of thumb and forefinger Crushes underfoot on a hard flat surface with small force
.... very strong	Crushes underfoot on a hard flat surface with full body weight applied slowly
.... rigid	Cannot be crushed underfoot by full body weight applied slowly
Deeply weathered	Rocks which have been partially or completely weathered to ferricrete
Dispersible soil	Structurally unstable soil which readily disperses into its constituent particles (clay, silt, sand) in water; also referred to as **dispersive**; highly dispersible soils are highly erodible
Dispersive	see **Dispersible soil** and **Soil dispersion**
Earths	Soils with a sandy, loamy or clay loam surface soil gradually increasing to a loamy or clay subsoil
.... massive	Earths in which the subsoil is not arranged into natural soil aggregates and appears as a coherent, or solid mass
.... structured	Earths in which the subsoil is arranged into natural soil aggregates which can be clearly seen
Electrical conductivity	A measure of the conduction of electricity through water or a water extract of soil; it is used to determine the soluble salts in the extract and hence *soil salinity*
Ferricrete	A layer formed from the weathering of rocks in humid tropical conditions and consisting mostly or iron and aluminium oxides; a complete laterite exposure will display a strong, hardened reddish surface horizon (which can contain 90-100% iron) breaking up with depth into a mottled (red, yellow, grey) horizon, which in turn passes down to a (white) pallid zone and finally reaching bedrock
Field texture	Soil texture is determined by the size distribution of mineral particles finer than 2 mm and is an estimate of the percentage clay, silt and sand; it is estimated in the field by measuring the behaviour of a small handful of soil when moistened and kneaded into a ball and then pressed out between thumb and forefinger
Fine grained sedimentary rocks	see **Sedimentary rocks .... fine grained**

Flood plain	An alluvial plain characterized by frequently active erosion and aggradation by channelled or overbank stream flow
Gilgai	Gilgai is surface microrelief associated with soils containing clays that swell upon wetting and shrink upon drying; gilgai consist of mounds and depressions sometimes separated by an almost level surface
.... linear	Long, narrow, parallel, elongate mounds and broader, elongate depressions more or less at right angles to the contour; usually in sloping lands
.... melonhole	Large depressions, usually greater than 3 m diameter and deeper than 0.3 m, which have a sub-circular or irregular shape and are separated by elongate mounds or set in an almost level surface
.... normal	Small, irregularly distributed mounds and sub-circular depressions, usually with less than 0.3 m vertical interval between the mound tops and bottom of depressions
Gradational soils	Soils in which the texture gradually increases with depth below the surface; there are no sudden texture changes between the sandy loam to clay loam surface layers and the sandy clay loam to clay subsoils
Gravel	A mixture of coarse mineral particles larger than 2 mm diameter; the individual particles may be either separate from each other (unconsolidated) or bonded together (cemented) by chemical agents
Gypsum	A naturally occurring soft crystalline mineral which is calcium sulfate; contains approximately 23 percent calcium and 18 percent sulfur and is a source of these nutrients
Horizon	A layer of soil, roughly parallel to the land surface, with morphological properties different from layers below and/or above it
Infertile topsoil	Soil material that is suitable for stripping and re-use as planting media <u>but</u> with such low nutrient content that plant establishment and growth may be restricted
Jump-up	A narrow ridge bounded by moderately inclined side slopes or steeper scarps and with a level to gently inclined ridge crest
Laterite	see **Ferricrete**
Levee	A very long, low, narrow, nearly level, sinuous ridge immediately adjacent to a stream channel that is built up by overbank flooding
Lime	A naturally occurring calcareous material used to raise the pH of acid soils and *l or* supply nutrient calcium for plant growth; the term normally refers to ground limestone ($CaCO_3$)
Loams	Soils with a uniform "loamy" texture of loam, silty loam and/or sandy clay loam throughout the soil profile
Massive earths	see **Earths .... massive**

Massive structure	see **Soil Structure .... massive**
Melonhole gilgai	see **Gilgai .... melonhole**
Mulch	Vegetation that has been shredded and applied either as a blanket cover on top of the soil surface or incorporated into the topsoil
Non-cracking clays	see **Clays .... non-cracking**
Non-sodic	Soil material that has an ESP of less than 6
Overland flow	Water movement across the land surface from the top of a slope towards a watercourse
Overland flow path	Part of a sloping land surface on which overland flow concentrates due to its relative lower elevation compared with other parts of the slope; an overland flow path may vary in relief from several centimetres to several metres and may vary in width from several metres to several hundreds of metres; it may only be evident after close inspection of the land surface
Ped	A natural soil aggregate that consists of a cluster of primary particles clearly separated from adjoining aggregates
pH	A measure of the acidity or alkalinity of a soil; a pH of 7.0 denotes neutrality, higher values indicate alkalinity and lower values indicate acidity; it is the negative logarithm of the hydrogen ion concentration
Run-on	Water that accumulates at a site (compared with runoff water that exits a site)
Saline soil	A soil which contains sufficient soluble salts to adversely affect plant growth and/or land use. See also SOIL SALINITY.
Sand	A soil separate consisting of particles between 0.02 and 2.0 mm in equivalent diameter. Fine sand is defined as particles between 0.02 and 0.2 mm, and coarse sand as those between 0.2 and 2.0 mm
Sands and sandy loams	Soils with a uniform "sandy" texture of sand, loamy sand, clayey sand and/or sandy loam throughout the soil profile
Sedimentary rocks	Rocks formed from the accumulation of material which has been weathered and eroded from pre-existing rocks, then transported and deposited as sediment by wind, water or ice; the sediments can be compacted and cemented together to form sedimentary rocks such as sandstone, or precipitated from material dissolved in water to form sedimentary rocks such as limestone
.... coarse grained	Sedimentary rocks with mainly sand sized particles and gravels, such as sandstone and conglomerate
.... fine grained	Sedimentary rocks with mainly clay and silt sized particles and very little sand, such as siltstone, claystone and mudstone

Silt	A soil separate consisting of particles between 0.002 and 0.02 mm diameter
Slaking	The natural collapse of a soil aggregate in water due to its low mechanical strength being insufficient to withstand the force of air being compressed within the aggregate
Sodic soil	see **Sodicity**
Sodicity	A measure of the Exchangeable Sodium Percentage (ESP) of soil material Soil material with an ESP of <6 is referred to as non-sodic Soil material with an ESP of 6-15 is referred to as sodic Soil material with an ESP >15 is referred to as strongly sodic
Soil ameliorant (Soil conditioner)	A substance used to improve the chemical or physical qualities of the soil
Soil dispersion	The process whereby *soil aggregates* break down and separate into their constituent particles (clay, silt, sand) in water, due to deflocculation
Soil fertility	The capacity of the soil to provide adequate supplies of nutrients in proper balance for the growth of plants, it can be divided into three components: Chemical fertility, Physical fertility and Biological fertility
Soil structure	Soil structure refers to the arrangement (distinctness, size and shape) of natural soil aggregates
.... single grain	Loose incoherent mass of individual particles with no observable natural soil aggregates; when displaced, soil separates into ultimate particles
.... massive	Coherent mass with no observable natural soil aggregates; when displaced, soil separates into fragments which maybe crushed to ultimate particles
.... weak	Natural soil aggregates are indistinct and barely observable in undisplaced soil; when displaced, up to one-third of the soil material consists of aggregates
.... moderate	Natural soil aggregates are well formed and evident but not distinct in undisplaced soil; when displaced, more than one-third of the soil material consists of aggregates
.... strong	Natural soil aggregates are quite distinct in undisplaced soil when displaced, more than two-thirds of the soil material consists of aggregates
.... coarse	Natural soil aggregates are relatively large with an average size (across the least dimension) of more than 50 mm
.... medium	The average size of the natural soil aggregates is between fine and medium
.... fine	Natural soil aggregates are relatively small with an average size (across the least dimension) of 20 mm or less

Structured earths — see **Earths .... structured**

Soil salinity — The characteristic of soils relating to their content of water-soluble salts. Such salts are predominantly sodium chloride but sulfates, carbonates and magnesium salts occur in some soils

Soil organic matter — That fraction of the soil including plant and animal residues at various stages of decomposition

Subsoil — Soil layers (horizons) below the surface with one of the following attributes:

- a larger content of clay, iron, aluminium, organic material (or several of these) than the surface and subsurface soil;
- stronger colours than those of the surface and subsurface soil above or the substrate material below

Subsurface layer — Soil layer(s) immediately below the surface layer which usually have less organic matter, paler colours and may have less clay than the surface layer

.... bleached — Subsurface soil that is white, near white or much paler than adjacent soil layers

Surface condition — Surface condition refers to the characteristic appearance of the surface soil when dry

.... cracking — Cracks at least 5 mm wide extends upwards towards the surface

.... crust — A distinct layer, often laminated, ranging from a few millimetres to a few tens of millimetres, which is hard and brittle when dry and cannot be readily separated from the underlying soil material

.... firm — Coherent mass of individual particles or aggregates; surface is disturbed or indented by moderate pressure of the forefinger

.... flake — A thin, massive surface layer (usually less than 10 mm thick) which, on drying, separates from and can be readily lifted off the soil below

.... hard setting — A compact, hard surface forms on drying but softens on wetting; when dry, the material is hard below any surface crust or flake that may occur, and is not disturbed or indented by pressure of forefinger

.... loose — An incoherent mass of individual particles or aggregates; surface easily disturbed by pressure of forefinger

.... self-mulching — A strongly structured, loose, surface mulch in which the aggregates fall apart naturally as the soil dries; a **fine** self-mulching surface has natural aggregates that are commonly less than 5 mm in dimension; a **coarse** self-mulching surface has natural aggregates that are commonly greater than 5 mm in dimension

.... soft — A coherent mass of individual particles or aggregates. Surface easily disturbed by pressure of forefinger

Surface layer	The soil layer (horizon) extending from the soil surface down, which has some organic matter accumulation and is usually darker in colour than the underlying soil layers
Terrace	A flat aggraded or eroded by stream flooding that is standing above a scarp; now defined as land that represents as land that represents a former flood plain on which alluvial deposition and erosion are barely active or inactive
.... high	A term frequently used in Queensland to describe a terrace that is a former flood plain on which alluvial deposition and erosion are barely active or inactive
.... low	A term frequently used in Queensland to describe a flat that continues to be subject to flooding; see **Channel bench**
Texture grade	A particular category of field texture, varying from sand to heavy clay
Texture contrast (TC) soils	Soils with a sandy to loamy surface material (including clay loam) suddenly changing into a clay subsoil
.... colour	The colour of a texture contrast soil refers to the colour of the clay subsoil
.... depth	The depth of a texture contrast soil refers to the total depth of surface soil and clay subsoil
Trace element	See **Plant nutrient .... Trace elements**
Tunnel erosion	The removal of subsoil by water while the surface remains relatively intact; also referred to as piping
Uniform soils	Soils in which texture differences between the surface soils and subsoils are minimal
.... coarse textured	see **Sands and sandy loams**
.... medium textured	see **Loams** and also see **Clay loams**
.... fine textured	see **Clays**
Valley flat	A small level to gently inclined flat aggraded and eroded by stream flooding and often enclosed by hill slopes

Based on the Australian soil and land survey field handbook (The NCST 2009).