CSIRO AGRICULTURE AND FOOD
www.csiro.au

Field Protocol to APSoil characterisations

Version 5 - October 2016

Written as part of GRDC Project CSP00170, a GRDC Partner Project

Citation

Verburg K (2016) Field Protocol to APSoil characterisations. Version 4. CSIRO, Australia.

Copyright and disclaimer

Important disclaimer

Contents

Acknowledgements

The research described in this report was undertaken as part of project CSP00170 'Measuring and managing soil water in Australian agriculture'. We thank CSIRO, the Grains Research and Development Corporation (GRDC) and the growers supporting GRDC for their funding support.

The field methodology for characterising plant available soil water was developed by Neal Dalgliesh and co-workers and collaborators. The advice contained in this report benefitted from the input from project team members, collaborators, those working on earlier projects and other soil scientists. Yvette Oliver, Mike Wong, Mark Thomas, Damien Mowat, Tim McClelland, Harm van Rees, Anne Jackman, Mark Glover, David Smith, Steve Henry, Neil McKenzie, Hamish Cresswell, Anthony Ringrose-Voase, Peter Wilson, James Hunt, Brett Cocks, Tony Webster, Ainsleigh Wilson, and Neal Dalgliesh thank you for your input and discussions.

When to use this Field Protocol to APSoil characterisations?

APSoil is a database of soil water characteristics enabling estimation of Plant Available Water Capacity (PAWC) for individual soils and crops. It covers many cropping regions of Australia and is regularly updated. It is designed for use in simulation modelling and agronomic practice.

Most of the characterisations contained in the APSoil database are based on a field methodology developed by Dalgliesh and co-workers and described in detail in a publication available from the GRDC website:

> *Burk L, Dalgliesh N (2013) Estimating plant available water capacity. GRDC Kingston ACT* http://www.grdc.com.au/GRDC-Booklet-PlantAvailableWater

This *Field Protocol* was written to support those who use the field PAWC method to prepare characterisations for inclusion into the APSoil database. It aims to provide more consistency in the data collected and shares some tips and tricks.

As the guide by Burk and Dalgliesh (2013) already provides detailed instructions, these are not repeated here. This *Field Protocol* provides some reminders, extra advice and information, as well as a list of complementary field observations that are requested to inform subsequent data processing and assist users of the APSoil database to extrapolate from the point-based measurements.

A separate document, also available from the APSoil website, describes the preparation of APSoil records:

> *Dalgliesh N, Hochman Z, Huth N, Holzworth D (2016) A protocol for the development of APSoil parameter values for use in APSIM. CSIRO.* https://www.apsim.info/Products/APSoil.aspx

Approval from landowner

See Burke and Dalgliesh (2013) page 6.

Soil PAWC characterisations in APSoil are geo-referenced. As APSoil is made available via Google Earth as well as an iPad app 'SoilMapp', this means the site locations can identify the actual paddock. It is important that land owners are aware of this prior to the work starting. The project has prepared a proforma letter for this purpose 'Characterisation commencement advice'. While sites can be included with an approximate location (e.g. nearest town), this largely defeats the purpose of the data being publically available as that prevents extrapolation of properties as that relies on an understanding of soil types and landscape position.

According to the 'Characterisation commencement advice' we will present the data to the land owner at completion of the activity and at least 1 month before public release.

To do:

- Notification (in writing) to the land owner using customised version of the proforma letter
- At completion, provide land owner with a copy of the data and reiterate its intended public and geo-referenced availability.

Locating the characterisation site in the landscape

See Burke and Dalgliesh (2013) page 6.

Burke and Dalgliesh (2013) list a set of required data on page 6 that locate a site. Note that while local property names may be used during execution of the work, these need to be removed when the data are entered into APSoil and should not be used in any public documents (including e.g. presentation slides).

The required data by Burke and Dalgliesh (2013) 'put a site on the map', but this information is not sufficient to allow users of the APSoil database to interpret and extrapolate from the site. To extrapolate from the APSoil point data to a location of interest requires the ability to recognise similarities in soil physical and chemical properties. As these properties are tightly linked to a soil's development and position in the landscape, extra information describing these is requested.

Key to Australian Soil Orders

The Australian Soil Classification (ASC) is described in detail in:

Isbell (2002) The Revised Edition of the Australian Soil Classification. CSIRO Publishing, Melbourne.

An online version of the classification is available at:
http://www.clw.csiro.au/aclep/asc_re_on_line/soilhome.htm

The table below provides a brief summary of the soil orders and the features that allow them to be classified. It represents the order of classification in the online key, which sequentially considers each of these orders (hence starting with 'Other soils...'). Classifying features should be considered in this order!

For classification of suborders, see the links provided for each order or the online or print version of the Australian Soil classification. The suborder can provide additional information, but is an optional entry.

Table 1: Australian Soil Orders, abbreviated description of classifying features, see full classification online for more detail.

ASC Soil Order	Classifying features (in order of appearance)
ANTHROPOSOLS	Soils resulting from human activities
ORGANOSOLS	Soils that are not regularly inundated by saline tidal waters and either: • Have more than 0.4 m of organic materials within the upper 0.8 m; or • Have organic materials extending from the surface to a minimum depth of 0.1 m; overlie rock or other hard layers or overlie fragmental material such as gravel, cobbles or stones in which the interstices are filled or partially filled with organic material.
PODOSOLS	Other soils that have a B horizon with illuvial accumulations of amorphous organic matter-aluminium and aluminium-silica complexes, with or without iron (a Bs, Bhs or Bh horizon).
VERTOSOLS	Other soils that: • Have a clay field texture or 35% or more clay throughout the solum except for thin, surface crusty horizons 0.03 m or less thick, **and** • Unless too moist, have open cracks at some time in most years that are at least 5 mm wide and extend upward to the surface or to the base of any plough layer, self-mulching horizon, or thin, surface crusty horizon, **and** • At some depth in the solum, have slickensides and/or lenticular peds.
HYDROSOLS	Other soils that are saturated in the major part of the solum for at least 2-3 months in most years (ie. includes tidal waters).
KUROSOLS	Other soils with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon is strongly acid.
SODOSOLS	Other soils with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon is sodic.
CHROMOSOLS	Other soils with a clear or abrupt textural B horizon and in which the major part of the upper 0.2 m of the B2 horizon is not strongly acid.

CALCAROSOLS	Other soils that are either calcareous (presence of carbonate segregations or fine earth (soil matrix) effervescence with 1M HCl) throughout the solum - or calcareous at least directly below the A1 or Ap horizon, or within a depth of 0.2 m (whichever is shallower). Carbonate accumulations must be judged to be pedogenic, ie. are a result of soil forming processes in situ (either current or relict) in contrast to fragments of calcareous rock such as limestone or shell fragments.
FERROSOLS	Other soils with B2 horizons in which the major part has a free iron oxide content greater than 5% Fe in the fine earth fraction (<2 mm). Soils with a B2 horizon in which at least 0.3m has vertic properties are excluded (see also Comment and footnote in Ferrosols).
DERMOSOLS	Other soils with B2 horizons that have structure more developed than weak throughout the major part of the horizon (soil peds well formed and evident).
KANDOSOLS	Other soils that: • Have well-developed B2 horizons in which the major part is massive (separates into fragments rather than peds) or has only a weak grade of structure, **and** • Have a maximum clay content in some part of the B2 horizon which exceeds 15% (ie. heavy sandy loam, SL+).
RUDOSOLS	Other soils with negligible (rudimentary) pedological organisation apart from the minimal development of an A1 horizon or the presence of less than 10% of B horizon material (including pedogenic carbonate) in fissures in the parent rock or saprolite. The soils are apedal or only weakly structured in the A1 horizon and show no pedological colour change apart from darkening of an A1 horizon. There is little or no texture or colour change with depth unless stratified or buried soils are present. Cemented pans may be present as a substrate material.
TENOSOLS	Other soils.

Local soil classification

Where this is available it is useful to include a local soil classification. While not necessarily valid for extrapolation outside the local region, it can provide valuable information for interpretation and extrapolation of soil properties within the region.

Soil type, texture or other descriptor

APSoil's naming of sites is usually based on the entry in the record field 'Soil type, texture or other descriptor.' With many practitioners unfamiliar with formal soil classification, this field usually contains a description of the soil on the basis of its texture, e.g. silty loam over medium clay. You can use field texture or base it on a prediction based on particle size analysis.

Predicting texture from particle size analysis

When using particle size analysis to estimate texture it is important to use a texture triangle (or matching set of equations) that is based on the particle size fractions used in the analysis. In Australia it is recommended to use:

Clay < 0.002 mm, 0.002 mm < Silt < 0.02 mm, 0.02 mm < Sand < 2 mm

A matching triangle (Figure 1) is provided on page 163 of:

Australian Soil and Land Survey Field Handbook (3^{rd} Ed.). CSIRO Publishing, Melbourne. ('Yellow book')

The software Soil Water Express, which provides predictions of PAWC from particle size analysis, chemistry used in conjunction with local calibration against soil water probe measurements, includes a calculator of texture:

http://www.apsim.info/swe/

As texture predicted from particle size analysis is only a prediction (it misses e.g. effects of organic carbon, structure, gravel) it is good practice to include a comment that texture was predicted from 'PSA' in the comments field of the APSoil record.

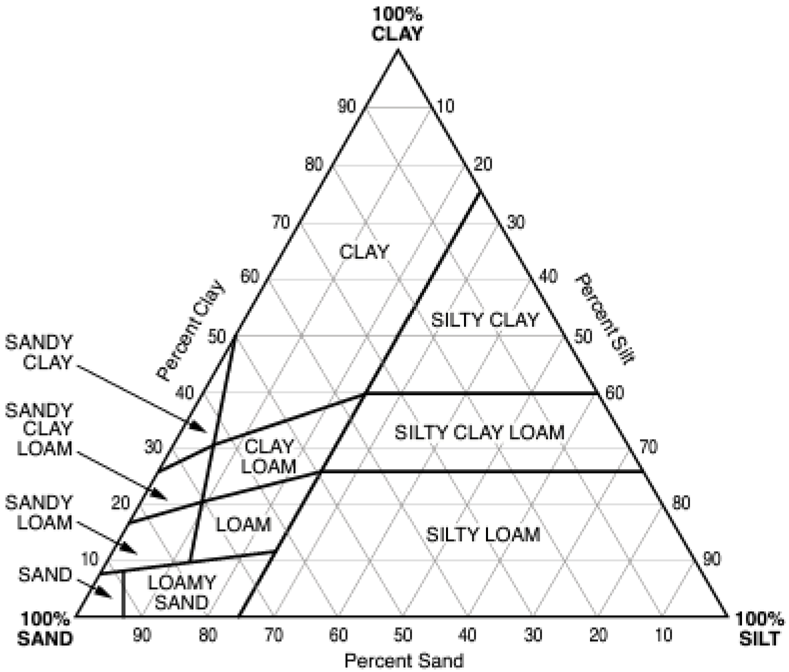

Figure 1: Texture triangle used to estimate texture from particle size analysis (Source: Marshall (1947) in The National Committee on Soil and Terrain (2009) Australian Soil and Land Survey Field Handbook, Third Edition. CSIRO Publishing, Melbourne.).

Description of landforms

In many landscapes the position of a soil in the landscape influences its properties. In addition to geo-referencing the site it can hence be useful to know about the landform when trying to extrapolate information from the APSoil sites to other locations of interest.

Soil surveyor's descriptions of landform are described in detail on pages 15 – 72 in the
Australian Soil and Land Survey Field Handbook (3rd Ed.). CSIRO Publishing, Melbourne. ('Yellow book')

For purposes of locating the characterisation site in the landscape draw on specifications of landform pattern and elements in this Handbook or the simplified guidance provided below in Table 2. While identification and description of landform will often be based on interpretation of landforming processes that may require a background and training in geomorphology, for purposes of allowing extrapolation from the APSoil site, any information may sometimes be better than none! Where uncertain about your interpretation, please check with local experts (e.g. State Department or CSIRO) before including the information.

Information contained in local soil survey or land system reports may provide helpful background to assist in interpreting the landscape and resulting soil characteristics. Examples of some on-line resources include:

- Victorian Resources Online (http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/vrohome).
  This website provides by catchment management region a compilation of all available soil and landscape information. This includes a brief description of landforms, often accompanied by a pdf map.

- NSW Soil and Landscape Information eSPADE (http://www.environment.nsw.gov.au/eSpadeWebapp/)
  This is a Google Maps-based information system that provides access to many thousands of soil profiles and for parts of the state soil landscape mapping or land system mapping. Where the latter mappings are available, pdf reports of the mapping units provide further information on the landscape and landforming processes. Most soil profile descriptions (also available in pdf form; zoom in close enough to see the red pins) contain information on landform, relief, slope and site processes that may assist if there is a nearby site. Note that for Riverine Plains land system information is available through ASRIS (see below).

- The South Australian State Land and Soil Mapping Program (1986-2012) is based on a nested hierarchy of mapping including land systems and soil landscapes (Hall, Maschmedt and Billing, 2009, The soils of southern South Australia, Dept Water, Land and Biodiversity Conservation). The mapping itself is available online at NatureMaps (http://www.environment.sa.gov.au/Science/NatureMaps). Reports for the land systems and soil landscape units are available on CD. Descriptions of soil characterisation sites in pdf form are available through NatureMaps (zoom in close enough for information layer to become available and use the Identify option).

- Soils data in Queensland is available at https://www.qld.gov.au/environment/land/soil/soil-data/).
  Queensland Globe (https://data.qld.gov.au/maps-geospatial/qld-globe) allows users to view and explore spatial data available across Queensland using the Google Earth application. The Soils Globe includes soil mapping, land system mapping and land resource assessment. Data sets needs to be requested and can then be downloaded from the link in an e-mail. A separate tool, Qspatial (http://qldspatial.information.qld.gov.au/catalogue/custom/index.page), also allows these spatial datasets to be requested (in a variety of formats) and supposedly the accompanying reports. The publications database provides access directly to the reports (https://publications.qld.gov.au/). The Land Resource Assessment mapping that accompanies a series of land management manuals draws on a description of soil-landscapes and landforms.

- Australian Soil Resource Information System (ASRIS) (http://www.asris.csiro.au/#)
  This resource provides a lot of information across the whole country in a GIS based tool. To get started, see the videos on the help page: http://www.asris.csiro.au/help.html. In relation to landform description, the ability to download soil profile descriptions for reference sites (make reference points layer in level 7 active (on the right hand side of page) , then use (lightning zigzag) hyperlink tool to access pdf) (on left hand side of page), and descriptions of land systems for West NSW, Riverine Plains NSW and Tas Land Systems (make relevant layer from level 4 active and use hyperlink tool to access pdf) may provide some assistance for site landform description.
- Soil and Landscape Grid of Australia (http://www.clw.csiro.au/aclep/soilandlandscapegrid/)
  This resource provides digital maps of the country's soil and landscape attributes based on measurements and spatial modelling. As the focus is on attributes, it does not provide landform descriptions as such.
- SoilMapp (iPad app) provides soil mapping as well as information for APSoil sites, ASRIS Reference sites and CSIRO Archive sites. The latter two usually include landform information, which while relevant only for those sites may still provide assistance.

The link between landscape position and sediment differentiation and resulting impact on soil types is illustrated in the following figure from
McKenzie et al. (2004) Australian Soils and Landscapes. An illustrated compendium. CSIRO Publishing.

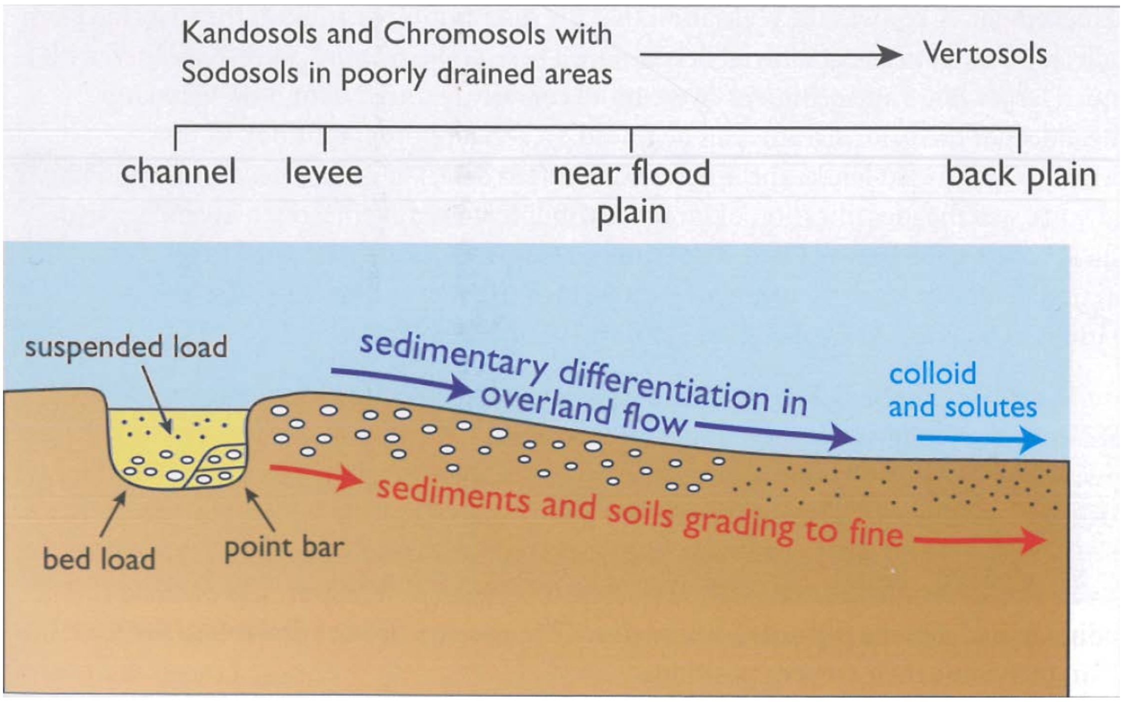

Figure 2: Sediment differentiation in an alluvial landscape, illustrating the landscape position impact on sediment differentiation and soil type (Source: Walker and Butler (1983) in McKenzie, Jacquier, Isbell, Brown (2004) Australian Soils and Landscapes, An illustrated compendium. CSIRO Publishing, Melbourne.).

Table 2: Brief description of key landform patterns and common landform elements based on definitions in the Australian Soil and Land Survey Field Handbook (Source: The National Committee on Soil and Terrain (2009) Australian Soil and Land Survey Field Handbook, Third Edition. CSIRO Publishing, Melbourne.).

Landform pattern	Typical / Common Landform elements (those under agriculture)
(Aeolian landscapes) Dunefield: level to rolling landform pattern of very low (9 - 30 m) or extremely low (0 - 9 m) relief without stream channels, built up or locally excavated, eroded or aggraded by wind.	Dune crest Dune slope Swale: linear, level-floored open depression excavated by wind or left relict between ridges built up by wind or waves, or built up to lesser height than them.
(Erosional landscapes) Hills: landform pattern of high relief (90 - 300 m) with gently inclined to precipitous (extremely steep) slopes. Fixed, erosional stream channels. Low hills: similar landform pattern, but of low relief (30 – 90 m) and gentle to very steep slopes. Rises: similar landform pattern, but with very low relief (9 - 30 m) and very gentle to steep slopes. Plain: level to undulating or, rarely, rolling landform pattern of extremely low relief (less than 9 m). (See Table 2 for slope classes.)	Hill crest Hill slope Drainage depression: shallow open depression with smoothly concave cross-section Foot slope: waning lower slope Valley flat: small, gently inclined to level flat, aggraded or sometimes eroded by channelled or overbank stream flow, typically enclosed by hill slopes; a miniature alluvial plain landform pattern. Plain: large, very gently inclined or level element, of unspecified geomorphological agent or mode of activity. See Figure 3
(Alluvial landscapes) Alluvial plain: level landform pattern with extremely low relief and shallow to deep alluvial stream channels. Active erosion and aggradation by channelled and overbank stream flow or the landform may be a relict from these processes. Flood plain: alluvial plain characterised by frequently active erosion or aggradation (50 yrs or less) Meander plain: flood plain with widely spaced, rapidly migrating moderately deep alluvial streams Terrace: former floodplain on which erosion and aggradation is barely active or inactive because deepening or enlargement of the stream channel has lowered the level of flooding.	Stream channel: linear, generally sinuous open depression, in parts eroded, excavated, built up and aggraded by channelled stream flow (with stream bed lower part and stream bank higher part) Scroll: curved, very low ridge built up by channelled stream flow and left relict by channel migration (meander plain). Swale: long, curve open or closed depression left relict between scrolls. Levee: very long, low, narrow, nearly level, sinuous ridge immediately adjacent to a stream channel, built up by overbank flow. Plain: large, very gently inclined or level element, of unspecified geomorphological agent or mode of activity. Backplain: large flat resulting from aggradation by overbank stream flow at some distance from the stream channel. Terrace flat/plain: small/large flat aggraded or eroded by channelled or overbank stream flow, no longer frequently inundated, part of a former flood plain. See Figure 2.

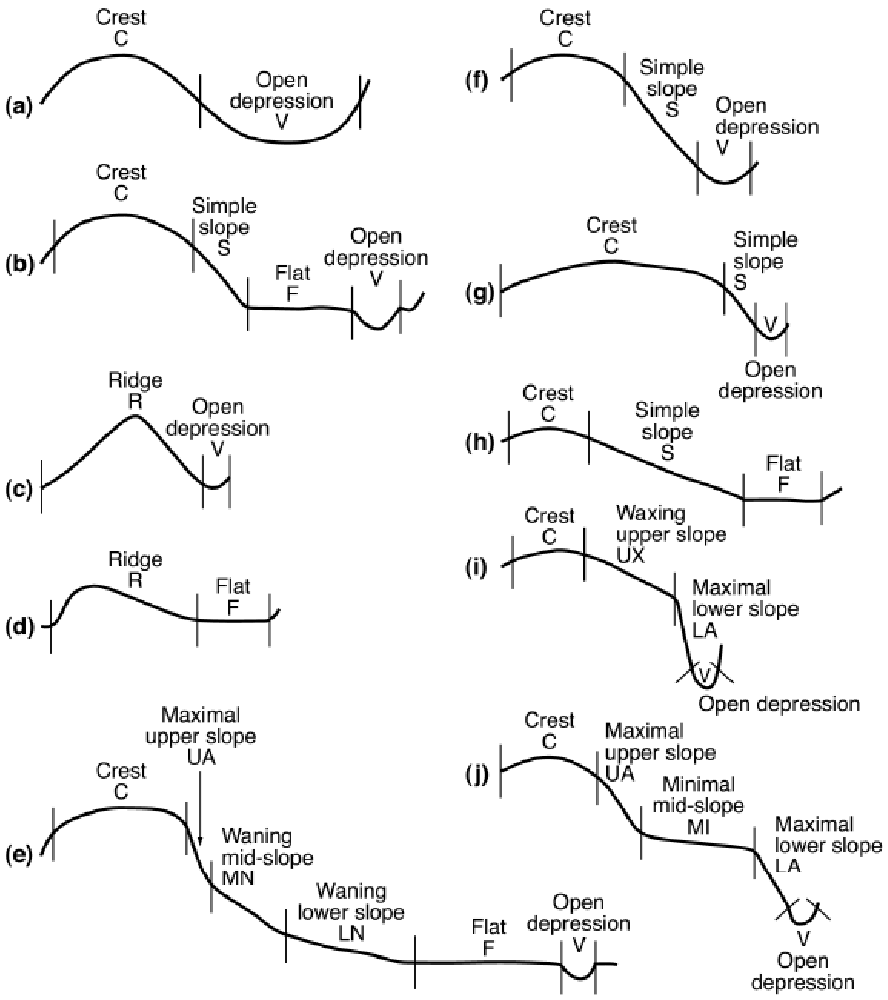

Figure 3: Examples of profiles across terrain divided into morphological types of landform element. Note that the boundary between crest and slope elements is at the end of the curvature of the crest. (Source: The National Committee on Soil and Terrain (2009) Australian Soil and Land Survey Field Handbook, Third Edition. CSIRO Publishing, Melbourne.)

Table 3: Slope classes based on slope tangent as percentage and average slope in degrees. See Australian Soil and Land Survey Field Handbook for more details. (Source: Modified from The National Committee on Soil and Terrain (2009) Australian Soil and Land Survey Field Handbook, Third Edition. CSIRO Publishing, Melbourne.)

Slope class	Tangent (%)	Average slope in Degrees
Level	< 1%	0° 20'
Very gently inclined	1 – 3%	1°
Gently inclined	3 – 10%	3°
Moderately inclined	10 – 32%	10°
Steep	32 – 56%	23°
Very steep	56 – 100%	37°
Precipitous	100 – 300%	60°
Cliffed	> 300%	80°

Drained Upper Limit (DUL) and Bulk Density (BD)

See Burke and Dalgliesh (2013) pages 7-12.

Part I of Burke and Dalgliesh (2013) provides detailed instructions on all aspects of characterisation for drained upper limit (DUL) and bulk density (BD). Please consider these instructions closely. Below a few pitfalls and common mischaracterisation issued (adapted from *Verburg et al. 2015 GRDC Research Update Wagga Wagga*, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Soil-characteristics-and-Yield-Prophet) as well as a check list for field notes during DUL and BD sampling. Most of these notes are for internal use to assist with soil profile classification and PAWC data checking. Typically only the information on soil colour would flow straight into the APSoil record, but some of the notes could be reflected in the comments field of the ultimate APSoil record.

Pitfalls and common mischaracterisation issues

- Weeds are often seen growing on the side of the plastic cover. It is important that these are strictly controlled. Burke and Dalgliesh (2013, page 8) recommend controlling all weeds and crops in a buffer area of 2m on all sides.
- In sandy-textured soils the concentric rings of dripper line must be laid sufficiently close to each other to ensure consistent wetting across the whole area. Burke and Dalgliesh (2013, page 8) suggest a distance of 30 cm on heavy clay soils and 15-20 cm on lighter soils, but that this should be confirmed for individual soils.
- Allowing insufficient time for drainage may lead to overestimation of DUL, especially at depth. Burke and Dalgliesh (2013; page 8) provides the following guidance: “Time will vary with soil texture. Deep sands will drain in a couple of days, medium-textured soils in about two weeks and heavy clays over a number of months, although drainage rates in heavy clays are so low that, practically speaking, soils can be sampled after one or two months.”
- Insufficient water application or application at too high a rate leads to underestimation of DUL at depth. This is particularly an issue with heavy clay soils, dispersive sodic soils and strong duplex (texture contrast) soils where water may move sideways. Appendix 1 of Burke and Dalgliesh (2013, p.16) provides guidance on amounts and page 8 on the rate of application. For strong duplex soils (and possibly sodic subsoils?) consider using an alternative irrigation system current being tested as part of the project’s work on “Protocols for difficult-to-characterise soils” (draft available upon request).
- The wetting and drainage processes may be monitored (e.g. using NMM or a moisture probe), see page 9 of Burke and Dalgliesh (2013).
- Where high levels of gravel prevent accurate bulk density samples (or prevents sampling all together) consider using the approach currently being trialled as part of the project’s work on “Protocols for difficult-to-characterise soils” (available upon request).
- Obtaining BD from intact cores (>75 mm diameter) may work for some soils e.g. moist sandy texture, but in many soils there is a significant risk of compaction, so that the manual method from Burke and Dalgliesh (2013) is preferred.
- Having a trench dug within the DUL wetting up area is an alternative to manual sampling to deeper and deeper depth. It has the advantage of providing a full profile description, information on spatial variability (e.g. depth of horizon changes), and being a visual display for the local landholders and other farmers and consultants in the area. Sampling in this case occurs in the wall of the trench.
- Soil variability may mean there is more than one PAWC profile within the paddock. It can also cause the DUL and CLL measurements to effectively be on different soils (even though they may be only 2-3 m apart). Taking a soil core at the time the shelter is erected can assist with interpretation as well as provide an indication of depth of wetting.
- Variability in depth of horizons, e.g. texture contrast between A and B horizons in duplex soils, can occur over small distances. This makes mixing replicates and selecting a “representative soil” difficult. Notes on depth of texture change in each replicate must be taken as these can assist with later interpretation of the DUL and BD data and for ‘matching up’ with data for the crop lower limit.

Soil chemistry

See Burke and Dalgliesh (2013) page 7.

The requirements for sampling for soil chemistry are outlined in Burke and Dalgliesh (2013, page 7).

Key points to note:

- Sampling may occur at any time, but is often done alongside the DUL and BD sampling.
- As described on page 7 of Burke and Dalgliesh (2013) take three cores per site and bulk across layers.
- Note that chemical samples should not be taken from within the irrigated area, in case the irrigation has affected the soil chemistry!
- Air dry samples for chemistry at 40°C
- It is useful to take an extra core at this stage for soil profile description and classification (take a photo!). If splitting that core in half, the other half could be brought along to workshops where the results are being discussed.
- We have found that landowners often enjoy receiving a soil core too.

Lab analyses

Below is a list of recommended lab analyses. Whilst not all of the listed parameters are directly used by the APSIM model, they do provide a more comprehensive physical and chemical picture of the soil which is often valuable in interpreting the particular soil situation and for setting appropriate parameter values related to water holding capacity (*).

Organic Carbon (OC)	Analysed using the Walkley Black methodology
Electrical Conductivity (EC)	
pH (H_2O)	
pH ($CaCl_2$)	
Chloride (Cl)	
*Boron (B)	Relevant if pH is high, some labs offer a conditional rule for analysis
*Cation Exchange Capacity (CEC)	
*Cations (Ca, Mg, Na, K)	Sometimes Al is included
Exchangeable Sodium (ESP%)	Calculated from the above
*Manganese (Mn)	Relevant if pH is low, some labs offer a conditional rule for analysis
*Aluminium (Al)	Relevant if pH is low, some labs offer a conditional rule for analysis
*Particle Size (PSA)	% sand, %silt and %clay; hydrometer and sieve technique
*% gravel	In soils with significant amounts of gravel, this value can be useful to convert fine earth analyses. It should ideally be measured quantitatively.

Crop Lower Limit

See Burke and Dalgliesh (2013) pages 13-15.

Part I of Burke and Dalgliesh (2013) provides detailed instructions on all aspects of characterisation for crop limit (CLL). Please consider these instructions closely. Below a few pitfalls and common mischaracterisation issued (adapted from Verburg et al. 2015 *GRDC Research Update Wagga Wagga*, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Soil-characteristics-and-Yield-Prophet) as well as a check list for field notes during CLL sampling. Most of these notes are for internal use to assist with soil profile classification and PAWC data checking. Typically only the information on soil colour would flow straight into the APSoil record, but some of the notes could be reflected in the comments field of the ultimate APSoil record.

Pitfalls and common mischaracterisation issues

- The CLL method as described above relies on crop roots exploring the soil to the fullest extent. If the crop has insufficient moisture to establish its root system prior to anthesis, the CLL may not reflect maximum soil water extraction. Roots will not grow through a dry layer even if there is moisture underneath. It is, therefore, important to perform CLL measurement in paddocks with a well established and healthy crop. Wetting up of the CLL site prior to the growing season may help, but requires close attention to weeds and to supplying the right amount of nitrogen fertiliser.
- Recording the depth at which roots are observed during the CLL soil sampling process is an important physical measure of depth of water extraction and very useful when analysing the soil data and developing the PAWC profile for the particular soil.
- In drier regions where the PAWC 'bucket' may not fill up may not provide the crop with moisture at depth. As a consequence CLL at depth could relate to a previous crop rather than the current crop. Taking a soil core for gravimetric moisture at the time of implementation of the rainout shelter (step 6 on page 13 Burke and Dalgliesh 2013) can be used to confirm whether the measured CLL was from the current or a previous crop.
- In wetter climates and years with rainfall in the weeks just prior to the erection of rainout shelters at anthesis may refill the PAWC 'bucket'. If the PAWC is large, this may prevent the crop from using all soil water and result in an overestimate of CLL (too wet). Ideally CLL is measured over multiple seasons, but this is rarely done in practice. Calibrated moisture probes can be an effective tool to assess a crop's ability to extract moisture over a range of different seasons. Tents can go on earlier if the profile is wet.
- The CLL measured for one crop type may not apply to a different crop type, especially where growing season length or susceptibility to subsoil constraints differs. It is possible that long-season varieties may extract water from a greater depth than short season varieties because of more extensive root development, and hence result in different CLL.
- If sampling is not deep enough to capture the full root zone, PAWC will be underestimated. In this case the CLL and DUL do not reach the same value at the bottom of the profile, but note that this could also happen if the profile did not wet up to depth and a past, deeper rooted crop's CLL is reflected in the measurements.
- Avoid the rainout shelter blowing loose or away by securing the sides firmly into the soil.
- For duplex soils located on hills slopes > 3-5% or soils at the break of slope subsurface lateral flow can cause soil wetting despite the presence of a well-constructed rain-out shelter. Keep an eye on late season rainfall and note any unusual wetness in samples collected.
- Sampling after harvest when the soils are dry and hard, or have hard layers can be tricky. Digging a soil pit can provide valuable information in these situations.
- Soil variability may mean there is more than one PAWC profile within the paddock. It can also cause the DUL and CLL measurements to effectively be on different soils (even when only 2-3 m apart).
- Variability in depth of horizons, e.g. texture contrast between A and B horizons in duplex soils, can occur over small distances. This makes mixing replicates and selecting a "representative soil" difficult. Notes on depth(s) of texture change(s) in each replicate can assist with later interpretation of the CLL data. It is also important to note these for later 'matching up' with data for DUL and BD.
- Processing the 3 cores separately rather than bulking them allows variability between cores to be assessed.

<intentionally left blank>

Field Protocol to APSoil characterisations - Checklists

Checklist site location (published information)

☐	Temporary Site ID	
☐	Country	
☐	State	
☐	Region (use the Bureau of Meteorology regional boundaries for each state)	
☐	Nearest town	
☐	Site location (local district or road or some other locally recognisable identifier, but not property name)	
☐	GPS Coordinates (decimal degrees)	
☐	GPS datum (preferably WGS84) and location accuracy (indicated on GPS unit)	
☐	Year of characterisation	
☐	Data source: collaborating consultants' name(s), Project funder (e.g. GRDC) & name (e.g. Measuring and Managing Soil Water in Australian Agriculture)	
☐	Australian Soil Classification order	
☐	Australian Soil Classification sub-order	
☐	Local soil name (and source if applicable, e.g. MySoil)	
☐	Soil description (typically texture, including depth of texture change; but could include other descriptor)	
☐	Other soil features: e.g. duplex, self-mulching, cracking, soil's tendency to form a crust seal, till layer hard-setting, etc.	
☐	Natural Vegetation	
☐	References to any soil-landscape mapping units and relative positions within units (include source)	
☐	Landform information	
☐	Slope at site (%; within ~ 20 m radius)	

Checklist site location (data that will not-be published)

☐/☐	Land owner letter / results sent	
☐	Land owner name, address, mobile and/or e-mail	
☐	Collaborator name, organisation, mobile and/or e-mail	
☐	Site history (current stubble type, current crop, cropping/land-use history)	
☐	Other notes	

Field notes Drained Upper Limit and Bulk Density

☐	Temporary Site ID	
☐	Date of DUL Pond set up	
☐	DUL plot size	
☐	Details on individual watering events (if available)	
☐	Last watering date	
☐	Total amount of watering (L or mm)	
☐	Photos of soil, site, wetting up, landscape taken (for future reference and assistance in data interpretation)	
☐	People sampling	
☐	Date of sampling	
☐	Sampling method DUL (manual, deep core, trench, ...)	
☐	Sampling method BD (and note ring diameter and height on data sheet)	
☐	Chemistry samples taken separately or at CLL	
☐	Issues with wetting up or sampling: e.g. condensation moisture on plastic that may contribute to increase soil moisture in first later, layers that do not seem to have drained, layers that proved difficult to sample, depth of wetting, presence of weeds, etc.	
☐	Soil colour (Munsell colour of moist soil) (note by layer on data sheet)	repeat
☐	Munsell colour code (note by layer on data sheet)	repeat
☐	Note presence of mottles, segregations, gravel and type of gravel (note by layer on data sheet)	
☐	Field texture (as a backup to texture from PSA) (see Appendix 2 on p.17 of Burke and Dalgliesh 2013). Note by layer on data sheet, but if this does not provide sufficient information, note depth(s) of texture change(s) here as well.	
☐	Any other observations that may assist with soil classification (e.g. depth of horizon changes, especially A-B horizon or texture contrast, structure, etc.)	

Field notes Crop Lower Limit

☐	Temporary Site ID	
☐	Date of rainout shelter set up	
☐	Crop	
☐	Variety and sowing date	
☐	Crop development at time of rainout shelter set up	
☐	Other notes on crop performance	
☐	Check list with site location details filled in	
☐	Photos of soil, site, landscape taken (for future reference and assistance in data interpretation)	
☐	People sampling CLL	
☐	Date of sampling CLL	
☐	Sampling method CLL (note core diameters on sheet)	
☐	Crop rooting depth (visible evidence, note for each core)	
☐	Chemistry samples taken separately or at DUL	
☐	Issues with rainout shelter or sampling: e.g. issues with rainout shelter, evidence surface runoff, layers that seem relatively wet, layers that proved difficult to sample, presence of weeds, etc.	
☐	Soil profile description info not already captured at DUL sampling or different from DUL sampling (e.g. depth of horizon changes, especially A-B horizon or texture contrast, structure, etc.)	
☐	Any other notes	

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

YOUR CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation.

FOR FURTHER INFORMATION

CSIRO Agriculture and Food
Kirsten Verburg
t +61 2 6246 5954
e Kirsten.verburg@csiro.au
w http://www.csiro.au/en/Research/AF