Technical Note: T20-4

# ESTIMATING SOIL PERMEABILITY FROM SOIL TEXTURE AND STRUCTURE: A simple short cut interpretation

**Figure 1 Manipulating the ribbon in the field test**


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# ESTIMATING SOIL PERMEABILITY FROM SOIL TEXTURE AND STRUCTURE: A simple interpretation

## 1. Introduction

Much emphasis is placed in AS/NZS 1547:2012 (herein referred to as the Standard) in replacing in-field measurements of soil permeability using a constant head permeameter (Appendix G, page 112) (see link Soil Permeability) with a pseudo-permeability factor assigned from soil texture analysis of one horizon of a soil profile. Perhaps there is a statistical, rather than empirical, equivalence between the texture assigned in the standard soil texture test (Section E4, page 105) and the values of indicative permeability, long term acceptance rates (LTAR) and design loading rates (DLR) (Table L1, page 145 and Table M1, page 160). But where is that validation? How do other properties modify the values in those tables?

The permeability of the soil profile cannot be assigned simply from a soil texture analysis without taking into account restrictive horizons of finer soil (more clayey), more permeable horizons (coarser texture), root channels, soil structure, fragments, shape of boundary horizons, voids of cracks and pores, causes of mottling and many other soil properties and characteristics.

To which horizon in the soil profile does the calculation of long term application rate apply? Is there a **limiting horizon**? The Standard (S5.2.2.3) only once makes reference to *depth to limiting horizons* without further elaboration as to how one or more horizons within a soil profile may influence site permeability. It cannot be construed that the reference to depth of the soil investigation *at least 1.5 m below disposal depth or until limited by unfavourable layer* (Table B1, page 86) refers to permeable features alone. The reference in Table K2 (page 137) with respect to *need at least 0.6 m of unsaturated soil below base* for absorption trenches, irrigation systems and ETA trenches and bed is not a reference to permeability, rather current saturation status.

With respect to identifying the site's permeable features, Geeves *et al*., 2000 (page 183) state that pore connections are important because *only pores that are connected in some way to both ends of the soil core can conduct water*. *The conductivity of a pore is assumed to be related exponentially to the pore radius.* It follows that predicting soil permeability from texture needs to be supported by *other simple direct indicators of permeability, or structure*.

So we need to understand the difference between soil properties (noun: inherited quality) and soil characteristics (adjective: quality by which it is distinguished from others) before we can even start to suggest that soil texture and perhaps one or two other soil characteristics can be used to assign a rate of movement of effluent through a soil profile. When we talk of water movement we must address movement in all directions, sideways, upwards and downwards, but to which horizon in the soil profile do we rate a long term application rate, or do we rate the whole profile on the most limiting horizon?

## 2. Assigning Soil Texture

Northcote (1979, page 26) states that *texture is a measure of the behaviour of a small handful of soil when moistened and kneaded into a ball and then pressed between the thumb and forefinger.* A further commentary on the method is that *the soil is moistened with water a little at a time…until the soil fails to stick to the fingers … the sticking point and approximates field moisture capacity….kneading and moistening continue until no apparent change in the soil ball…usually 1 to 2 minutes…now ready for manipulation…. the behaviour of the ball during formation of the bolus is indicative of its texture. Shearing the bolus between the thumb and the forefinger to form a ribbon characterises the texture.*

The property of the soil is its texture, the characteristic of a particular soil is the ribbon formed from the bolus and the grade of texture recorded. Figure 1 (cover page) shows a ribbon being formed in a red clay. The length of the ribbon is compared with the table in Northcote (1979), from which a texture is called, as set out in Appendix B.

The Australian Soil and Land Survey: Field Book. 3rd Edition (National Committee on Soil and Terrain, 2009, page 161) states that *soil texture is defined by the size distribution of mineral particles finer than 2 mm, that is, only material that will pass a 2 mm sieve should be used in determination of field texture*. The method is a 'field' method and is not the same as a particle size analysis performed in the laboratory (AS 1289.3.6.3).

The Australian soil textural grades are based upon the international fraction sizes (sand 2000-20 µm, silt 20-2 µm and clay <2 µm). The Australian Standard (AS 1289.3.6.3) uses the British Standard size fractions (sand 2000-60 µm, silt 60-2 µm and clay <2 µm). The Standard (AS/NZS 1547.2012) omits to state which system of classification is used; could it be because New Zealand uses the British system. How can the Standard meet the requirements of both countries and not indicate the difference between the two systems with respect to particle size fractions? Such an omission could be viewed as deceptive! The Standard doesn't acknowledge there is a particle size difference between the countries?

The soil texture groups (the characteristics of texture) are set out in Northcote (1979, page 29) as in Table 1:

Table 1. Soil texture grades for the six texture groups

| Texture Groups | Texture Grades |
|---|---|
| Sands | sand; loamy sand; clayey sand |
| Sandy loams | sandy loam; fine sandy loam; light sandy clay loam |
| Loams | loam; loam, fine sandy; silt loam; sandy clay loam |
| Clay loams | clay loam; silty clay loam; fine sandy clay loam |
| Light clays: | sandy clay; silty clay; light clay; light medium clay |
| Medium-Heavy Clays | medium clay; heavy clay |

The textural triangle, Figure 2, relates to the Australian nomenclature for the particle sizes for Australian soil science as referenced in NCST (2009, page 163)). Figure 3 is a similar triangle based upon a composite of the United States Department of Agriculture (USDA) and the British Standards system, the latter called up by New Zealand Soil Science. The difference in the particle sizes between these two systems is subtle, with silt being 2-50 µm for the former and 2-60 µm for the latter, compared to 2-20 µm in the Australian soil science system (Figure 2).

The EPA Vic *Code of Practice-onsite wastewater managemen*t (EPA 891.4, 2016) doesn't make reference to any soil texture classification system. The Victorian Resources Online (see References) uses the international fraction sizes, but employs the British textural triangle which is based on different particle size ranges and descriptions. How can that be? Are you confused?

What the miss-match of soil textural classification means is that one has to be very specific as to which system is being used, otherwise the separation of particle size by the different system and the different proportions of sand/silt/clay make simple translation of soil texture more complex. The differences become more important when one references overseas texts to infer soil texture characteristics, or even relate soil texture to soil permeability. It is critical to compare like with like, comparing terminology based on different particle size groups is clearly wrong.

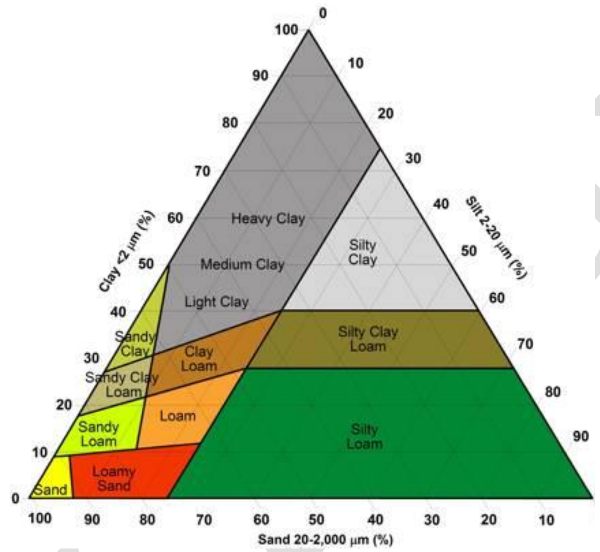



**Figure 2 International soil texture triangle used by Australian soil scientists**

http://www.terragis.bees.unsw.edu.au/terraGIS_soil/sp_soil_texture.html

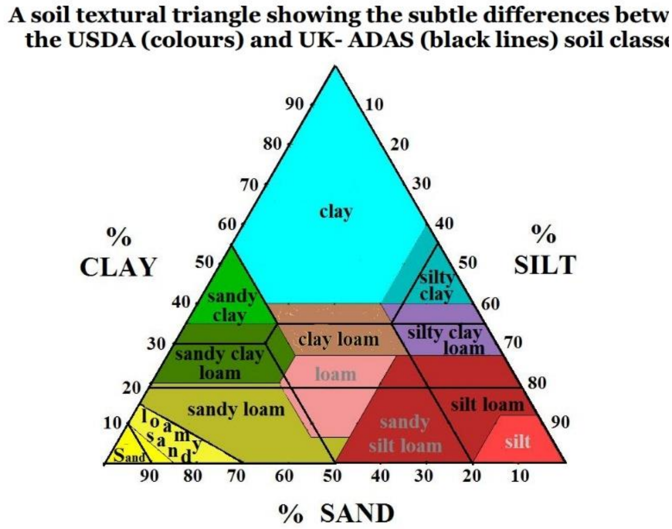



**Figure 3 Overlay of USDA and British Systems**

https://upload.wikimedia.org/wikipedia/commons/0/0d/USDA_and_UK-ADAS_textural_triangle.jpg

## 3. Examining Soil Texture in the Field

The application of the in-field soil textural classification can also be performed in the laboratory, where it may be easier to obtain an air-dried sample, sieved to provide soil of less than 2 mm particle size, minus roots and stones. One needs to be careful that in crushing the soil, stones and aggregates are removed and only soil mineral matter is selected for the test.

The difference between the in-field classification and the particle size analysis using a hydrometer (AS 1289.3.6.3-2003) is that the former will be influenced by the feelings of stickiness, greasiness, grittiness, stain, colour and plasticity; all of which are important characteristics. The latter sample is prepared for the hydrometer test where the organics are 'burnt out' using hydrogen peroxide ($H_2O_2$), a dispersant (sodium hexametaphosphate) is used to break up the clays, and the mixture of soil and water is either tumbled for hours or agitated violently before the test begins to separate individual particles. The results for the two tests are as different as chalk and cheese! The results from the hydrometer tests cannot be used to compare with the indicative permeabilities suggested in the Standard (Table 5.1, page 39), or can they? The Standard makes no clear distinction between the two methods of determining soil texture.

In the field, the soil profile needs to be described from the surface down through the various horizons to a depth of about 1 m, although the reference in the Standard, as set out in Section 1 above, is *at least 1.5 m below disposal depth or until limited by unfavourable layer* (Table B1, page 86). That depth for a septic trench would require an excavation to 2.0 m. Few, if any, consultants would investigate to that depth when the Standard (Table K2, page 137) only requires *0.6 m of unsaturated soil* below the bottom of the application depth: further conflicting advice.

It is important to determine the texture of the horizons underlying the irrigation area and/or the bottom of the trench as it will be these horizons that benefit or limit deep drainage; and the advice for a 0.6 m deeper investigation is valid. The property that is most limiting to water movement defines the rate of permeability, it is that which has the slowest permeability that dictates the loss of water, by percolation, at depth. It may be a combination of soil properties and characteristics that define that horizon; to simply accept texture and structure ignores other influences on permeability.

**Figure 4 Exposure of soil profile during site preparation**

**Figure 5 Soil auger with profile in circular layout**

**Figure 6 Post hole digger available on farm**

**Figure 7 Excavator opening an inspection pit**

**Figure 8 Shovel usually for shallow inspections**

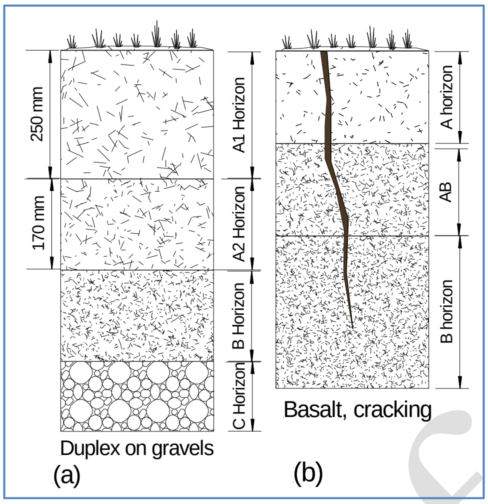
**Figure 9 Exposed face of pit**

So what equipment do we require to examine the soil profile to the appropriate depth? The examples in Figures 4-9 range from extreme to simplistic, but the tools must provide a suitable exposure of the horizons for one to examine their properties and describe their characteristics. The limitation of using a soil auger is that it is difficult to observe the interface between horizons, any longitudinal change in horizon boundaries, and impossible to determine soil structure. By their construction, the auger cuts into the soil and destroys the structure. Other soil augers, such as those from Dormer Engineering ([www.dormersoilsamplers.com.au](www.dormersoilsamplers.com.au)) while very effective at retrieving a soil sample from the auger hole, the soil will be considerably deformed such that the structure cannot be determined. Push-type hydraulic samplers may show some soil structure but require a large diameter cutting head; the typical 30-50 mm tube may not show sufficient detail.

That the other characteristics of structure (size and type of pedality) have been omitted from the Standard is either through ignorance or purposeful avoidance.

The soil pit, excavated by backhoe, as shown in Figure 9, to a depth of 1.2 m provides the ideal exposure of the soil profile and permits some longitudinal examination of horizons and their boundaries, unable to be detected using a soil auger or post hole digger. Let's use the example of Figure 10, for further discussion, where the soil profile has been exposed as a soil pit in the area proposed for effluent trenches.

Two distinctly different profiles are shown in Figure 10, indicating that a soil profile, because of parent material, can develop different arrangement of horizons due to soil forming factors. There are many varied arrangements of horizons.




A duplex profile is one where the difference in the texture of the surface A horizon is at least one and half texture groups (Table 1) different to the B horizon. Because of this texture difference, the usually higher permeability of the A horizon (A1 and A2), water movement is restricted when it reaches the more clayey B horizon. In some locations, the water will pond on the B horizon leading to excess water in the A2 horizon with consequences of dissolving and removing minerals when the water finally drains into the B horizon. The B horizon captures these mobile minerals, further changing the texture of the B horizon.

The basalt soil is generally a clay loam surface grading to a light clay then a medium to heavy clay, the arrangement and relative depths depending upon topography. For a black cracking clay, it is difficult, even in a backhoe excavation to clearly delineate the horizons within the meaning of term; a label (AB) is used. The permeability will be slow in all horizons and an A2 horizon will not form.

**Figure 10 Two profiles formed on different parent material**

It would be unreasonable to suggest that the water percolating through 10(a) would only be affected by drainage. The influence of the textural differences through the A, into the A2 and then the B could be pronounced. The site examination needs to determine any impediment to drainage that may limit on-site disposal of effluent.

## 4. Additional Soil Properties

If would be remiss of a site examiner if the other characteristics of each horizon were not observed and recorded at the same time, particularly as those characteristics may modify how the simple description of soil texture is affected by these other attributes or lead to more in-depth assessment of movement of water in the profile. While the Standard (Table B2, page 87) suggests additional soil properties to be 'assessed', it is unclear how those factors influence the Tables L1 and M1 (pages 145 and 160 respectively). Figure B1 (page 89) indicates that a range of in-field assessments be made, without mentioning how they influence Tables L1 and M1.

Northcote (1979, page 28) lists soil properties that affect the determination of texture as:

Clay – confers cohesion, stickiness and plasticity;
Type of clay mineral influences tractability;
Silt – confers silky smoothness;
Organic matter – confers cohesion on sandy textures and greasiness on clayey textures;
Oxides – many require more water to make bolus, and shear readily;
Ca-Mg carbonates – impart porridge like consistence to bolus;
Base saturation and cation dominance – Ca dominate clays accept water readily, Mg & Na difficult to wet; and
Strong fine-structured aggregation – tend to make texture feel less clayey.

The reader is directed to the additional discussion by Northcote (1979) and NCST (2009) in relation to those properties.

Mottles are known as 'redoximorphic features' that (reduction/oxidation/shape) arise when anaerobic (without oxygen) conditions exit, mostly through saturated soil conditions. Iron and manganese, leached from upper horizons, migrate to the anaerobic zones. Bright coloured mottles of yellowish brown to red are caused by oxidation as the iron changes colour from red (oxidized) to yellow (some water in crystal lattice) to grey (anaerobic zone). Manganese usually forms as manganese dioxide (black concretions) in anaerobic soil. Once formed these mottles persist even through the anaerobic zone may cease, so they need to be examined as current or relic. While the soil profile may be dry at the time of examination, these redoximorphic features are a record of other times, maybe recent or ancient. The soil surveyor needs to understand their significance, if any, and adjust the influence on soil permeability accordingly.

## 5. Soil Structure

### 5.1 Soil aggregates

Soils with the same texture, as described above, may have significantly different structure because of the arrangement of primary soil particles (sand, silt and clay) with organic and inorganic substances formed into stable units called soil aggregates (peds) that consist of solids and pore spaces (voids). Structure is the description of the form of these stable aggregates.

Numerous pore spaces encourage root penetration and pathways for water, nutrients and air. Cohesion (stick to itself) within these units is greater than the adhesion (stick to other things) among units, so that when the soil mass ruptures, it does so along the planes that form the boundary of the structural units (USDA, 2017, page 155). A single structural unit is called a 'ped', ranging from about 1 mm to 100 mm and with recognizable shapes (form) as set out in Figure 11. We identify these units when we excavate a soil pit as part of our description of the soil profile, with the strength of the ped generally increasing with depth.

The formation of these aggregates develops by processes of wetting and drying, freezing and thawing, exudates from soil microbes, soil fauna (earthworms, mites) and flora (fungi and plant roots), decomposition of organic matter, and adsorption of cations. Polyvalent cations ($Ca^{2+}$, $Mg^{2+}$, $Al^{3+}$, $Fe^{3+}$) bind clays together, while carbonates ($CO_3^{=}$) stabilise the aggregates. Lime ($CaCO_3$), dolomite ($CaMgCO_3$) and gypsum ($CaSO_4$) also used to stabilize clays.

The aggregates are described by:

- grade - degree and strength of soil aggregation;
- class - main size range of individual aggregates; and
- form – shape of individual aggregate.

While AS/NZS 1547.2012 is a joint document, the terminology for describing the aggregates varies slightly for 'form-shape of individual aggregate' between the two countries. Only the Australian terminology is discussed here.

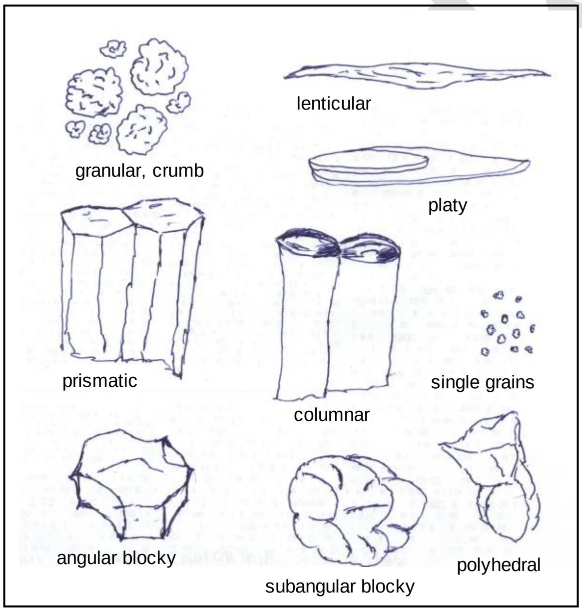



**Figure 11 Soil structural forms**

Recognisable forms include:
***crumb or granular*** - roughly rounded peds, usually lie loosely, may be non-porous (granules) or porous (crumb), usually found under grass near surface
***platy*** -arranged as thin horizontal plates, found near surface
***lenticular*** – lens shaped, thick in middle
***prismatic*** - vertically oriented aggregates or pillars the edges of which are well defined flat faces, the tops are plane, level and clean cut, usually B horizon, heavy clay.
***columnar*** - as for prismatic with the top of the prisms rounded or domed, usually B horizon, usually highly sodic
***angular blocky*** -aggregates arranged as blocks with six relatively flat roughly equal faces (almost a cube), corners of which are sharp (angular), common in B horizon
***sub-angular blocky*** - as above with flat and rounded faces with limited accommodation of surrounding peds.
***massive*** structure has no preferred zones of weakness and does not break into peds.

Highly structured forms such as prismatic, blocky and granular, tend to allow for easier passage of water and exchange of gases than do platy structure while little water penetrates massive structural units.

The question arises "can we change/enhance the structure in the land application area?", to which the answer is 'yes', but not a depth. At the surface we can incorporate organics including manures and crop residues, minimizing raindrop impact and avoiding compaction by vehicle traffic. We can add lime, gypsum or dolomite that may advance into lower horizons but the movement is likely to be slow.

New Zealand soil scientists use a novel approach to describing soil structure, as shown in Figure 12.

> Simply dig a hole about spade width and spade depth, put all the soil to one side. Then down one side of the hole, take a spade full of soil about 75 mm thick, lift out that wedge of soil, and from about waist high, drop the soil onto a hard surface. Sort the soil into several grades - Move all the larger lumps towards one end, and all the mid-size lumps into the middle and all the smaller lumps to the other end. This process can be repeated for various horizons as required.


**Figure 12 Soil structural analysis (Source: Sheppard *et al.*, 2000)**

While the exercise in Figure 12 makes farmers aware of the structural conditions of their agricultural lands, it is a simple method of examining the soil over time, its application for on-site wastewater management is obvious. The separation of soil aggregates according to size, also reveals the grade (degree and strength of aggregation), the class (main size range of individual aggregates) and form (shape of individual aggregates).

An excellent evaluation sheet for structure, complete with clear images, is available at
https://www.swarmhub.co.uk/wp-content/uploads/2018/10/VESS_score_chart-4.pdf

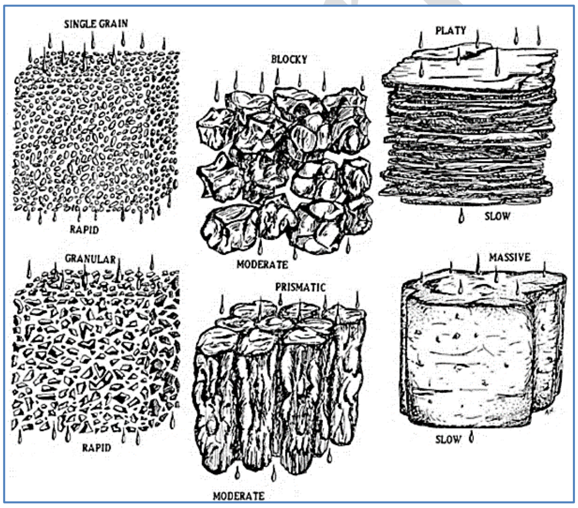



**Figure 13 Soil structure and water movement**

The movement of water vertically through soil peds of various forms is related to the open pores that are connected from the top to the bottom (continuity), how tortuous they are and their cross-section for either gravitational water (flows under force of gravity) or by slow drainage of capillaries.

Figure 13 shows typical structural forms with a suggestion of the drainage in soil horizons were these forms are found. In this respect the movement of water is downwards only and should not be interpreted as water that flows laterally (sideways) by capillary forces

Source:
https://research.wsulibs.wsu.edu/xmlui/bitstream/handle/2376/6758/eb1633.pdf
Engle CF, Cogger CG, Stevens RG. Role of soil in groundwater protection. WSU Cooperative Extension Bulletin. Washington State University, Prosser; 1991.

Appendix A provides additional photographs of augered soil profiles and how variations in colour and texture, horizon depths, profile complexity may vary from obvious to subtle, but structure is not one of those observations. It may be that the site examiner has local knowledge of the range of soil structures typical of this soil profile and that its influence on the permeability can be estimated in the absence of a proper visual examination from a pit exposure.

The Standard's five *Degrees of Structure* (Table E4, page 108), refer to terms 'massive', 'single grained', 'weak', 'moderate' and 'strong', are consistent with soil terminology for grade of pedality ((NCST, 2009, page 171). In Tables L1 (page 145) and Table M1 (page 160) the terms used are 'massive', 'weakly structured', 'moderately structured' and 'high/moderate structure', the term 'high/moderate' seems to correspond with 'strong'. These terms are simply subjective terms that simply relate to 'grade'. That the other characteristics of structure (size and type of pedality) have been omitted from the Standard is either through ignorance or purposeful avoidance. The term *Grade of Structure* as the only descriptor for 'structure' is incomplete.

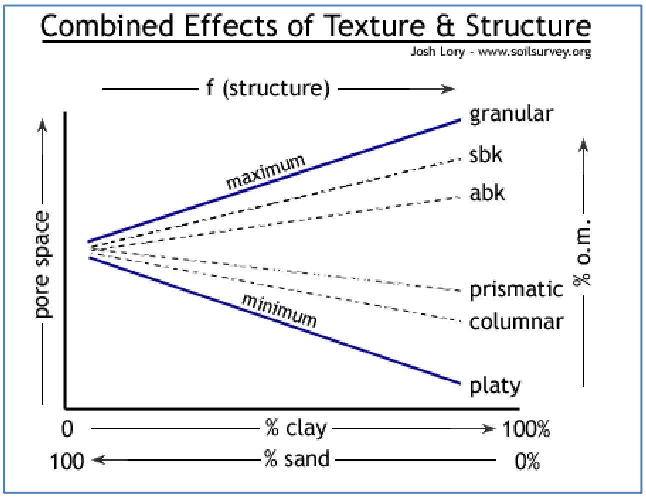



Figure 14 indicates the relationship between the soil's structure (grade, class and form of peds), and texture (% sand, silt and clay) with inclusion of organic fractions. The likely arrangement of the peds (structural form) are shown on the right, with the highest pores spaces (left hand axis) associated with the granular form, and the least pore space with the platy form.

The pore space is important for the storage of soil water, held between the field capacity and the permanent wilting point. It is this capacity to retain water that is utilised in the water balance modelling and the storage component that allows some flexibility in addressing losses and gains from the soil profile. To negate this storage capacity within the soil profile or trench, as in the NSW Guidelines (page 157) and the Standard (Equation Q3, page 181) simply creates unnecessarily large land application area.

**Figure 14 Relationship of structure, texture, organic matter and pore space**
(Source: www.theorangegardener.org/topics/soil/tilth/tilth)

The Standard (Q3, page 181) states *that that over the long term the increases and decreases in soil moisture content cancel each other out (DS=0) we can also see that for the sustainable operation is Equation 3.* What seems to be missed in this statement is that the soil moisture storage is a dynamic function within the soil profile, offering a reservoir of water for plant and animal survival and movement of water within the profile. To simply eliminate the storage capacity rather than including it in computer modelling is akin to suggesting that clouds don't affect climate because they come and go and overall add to zero.

That Equation 3 (page 181) has any credible place in the Standard is about kindergarten level of understanding! However, note that variable A in that equation is *effective area of infiltration (wetted bottom and side walls)* which contradicts (L4.1, page 143) that uses *bottom area only* for calculating DLR. Confused?

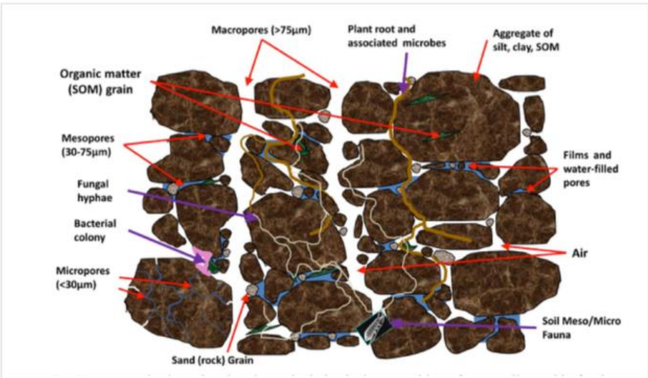



Fig. 5.1.1. Top: pie chart showing the typical physical composition of most soils used in food production; Bottom: Basic cross-section of approximately 20 mm wide of soil as a porous, biologically active mineral-organic matrix. Red arrows show non-living components while purple arrows show biological components. Large macropores resulting from good soil *structure* allow adequate drainage and air entry to a soil for biological activity, while smaller mesopores and micropores hold water at varying degree of availability for plant roots. Macrofauna such as earthworms (>2mm approximate dimension) are also very important but would occupy too much of the diagram to show.
*Credit: Steven Vanek, adapted from Steven Fonte.*

**Figure 15 Typical composition of soil, air and water**
Source: https://serc.carleton.edu/integrate/teaching_materials/food_supply/student_materials/1029

Figure 15 is a schematic cross-section of a soil horizon, showing a combination of soil fauna, soil structural units, pore spaces and channels that exist under natural conditions. It is the role of the site assessor to accurately determine the potential for effluent drainage, permeability, and storage within the land application area.

Perhaps, somewhere in the drafting of the Standard, the terminology for 'structure' was overlooked as only important for its 'grade" while the size and shape of the aggregates was ignored as irrelevant; a less than meaningful outcome. Unfortunately, one suspects that many site investigations ignore soil structure as a determining factors for soil permeability, misunderstanding the role it plays in soil water storage and transit.

### 5.2 Effects of salinity and sodicity on soil structure

Saline and/or sodic effluent can induce serious structural and hydraulic conductivity issues in the land application area. Similarly, saline and/or sodic conditions in the land application area can also create serious issues when discharging effluent as either irrigation or sub-surface flows.

Salinity promotes soil flocculation (soil particles aggregating) and sodicity promotes soil dispersion (particles separating). Soil dispersion hardens soil, blocks infiltration and lowers permeability which reduces the amount of effluent and rainfall that can enter and pass through the soil. Both surface soils and sub-soil horizons may be affected.

**Figure 16 Columnar soil aggregates**

Soils with well-defined structure will contain a large proportion of cracks and macropores permitting water to flow into and through the soil, as well as for temporary storage.

When sodic effluent (high $Na^+$, low EC) enters the soil, dispersion causes a loss of soil structure and reduces the hydraulic conductivity.

Figure 16 shows a natural highly sodic soil that has formed columns, with rounded tops, in the B horizon. The horizon sets extremely hard and is unlikely to allow water to penetrate so the only flow will be in the cracks between these very large aggregates, thus limiting the hydraulic conductivity of the proposed land application area. The quality of the effluent may further exacerbate the sodic conditions.

For surface irrigated effluent, the sodium in the effluent may cause the soil to disperse because of the combination of the low salinity (as measured by EC) and high sodicity. The dispersed clay particles move within the soil to block the soil pores so that when the soil dries, a hardened layer restricts water infiltration.

Both soil texture and soil structure affect the soil's drainage and aeration processes and, therefore, the hydraulic conductivity of the soil. To fail to appreciate and incorporate the structural classification as 'grade, class and form' suggests that one does not understand the interaction of these properties. It is possible to ameliorate the soil and/or the effluent to improve water movement into and through the soil by the use of lime, gypsum and/or dolomite to alter the SAR of the effluent, or the ESP of the soil. As a matter of course, the sidewalls and base of an effluent trench need to be powdered with lime or gypsum prior to backfilling with aggregate and soil. The purpose at this early stage is to reduce the impact of the first flush of effluent disrupting the newly excavated sidewalls and bottom areas.

The definition of *Sodic* in the Standard (page 17) is *a soil condition in which the percentage of exchangeable sodium is high enough to cause significantly increased clay dispersivity, decreased soil structure stability, and to potentially decrease soil permeability*. So how does one relate this to a test for dispersibility without actually testing the behaviour of the soil with domestic effluent? A sodic soil in the NSW Guidelines (DLG *et al*., 1998, Table 6, page 68) has been given a range of values for minor, moderate and major limitations. However, the Guidelines (page 72) inaccurately state that *Sodic soils tend to have low infiltration capability, low hydraulic conductivity*, when it can be shown that the hydraulic conductivity of sodic soils can be significantly improved using a high salinity water. The reader is directed to the Technical note T20-1 Emerson Aggregate Stability Test (link here)

### 5.3 Misuse of terminology

When we examine the use of the term soil permeability in the Standard (page 17) as *a calculated value derived from the rate at which a head of liquid* ***infiltrates*** *a particular soil, usually measured in m/d and often referred to as* $K_{sat}$ we can only shake our head in wonder as to how such a definition could be so wrong. Firstly, **permeability** is the movement of water through a soil, rather than **infiltration** that means water moving into soil. Secondly $K_{sat}$ is a measure of saturated hydraulic conductivity which occurs when all the soil pores are saturated. At less than saturated conditions the term unsaturated hydraulic conductivity ($K_{unsat}$) is used. Often these two terms are written without the using the subscript form for ease of typing, further confusing the difference.

The abbreviation for Ksat (Standard, page 18) is *saturated permeability coefficient* whereas at Comment:CB6 (page 88) – *soil permeability value Ksat.* So is it the former *coefficient* (a number used to multiply a variable) or the latter - a value? It cannot be both! It is only the latter, a value for Ksat.

The Standard (C5.1.1, page 34) suggests that *Important soil properties include soil texture, sodicity and dispersiveness, soil structure, and soil structural stability (AS 1289.3.8.1), presence, density, and sizes of biological pores – 'areal porosity' (see E8) – as well as soil bulk density, and soil permeability (hydraulic conductivity). Of these predictors, areal porosity has proved to be the most useful one. These predictors need to be correlated with measured permeability values in any given soil environment. ……… there are few documented correlations between measured permeability and LTAR. Y*et Tables L1 and M1 would suggest there is a reliable correlation otherwise the use of DLR and not LTAR would not be so compulsive.

That the reference to AS 1289.3.8.1 in the above paragraph, for the Emerson dispersion test is doesn't match with the test set out in Section E7 (page 109), the former reforming a small ball without touching one's hands, while the latter uses a reformed ball after the soil has been manipulated for texture assessment. The methods of obtaining the reformed ball are different, but only the former is correct.

If the *more accurate estimates for effluent Ksat values can be obtained by modifying the characteristics of the test water to better match that of the effluent* (Table 5.1, page 39), then why does the Standard even bother to use the term *indicative permeability based on clean water* when the purpose of the document is for wastewater as the title of the Standard states?

## 6. Conclusion

Both soil texture and soil structure affect the soil's drainage and aeration processes, but they are not alone in modifying the behaviour of a soil profile acting to dispose of domestic effluent back to the environment in the most efficient way with a minimal environmental footprint. The soil profile is unlikely to be a simple single texture from surface to below the effluent discharge point (about 100 mm for irrigation or 450 mm for a trench) and it would be unrealistic to even imagine the soil structure was the same from surface to depth for numerous reasons. Yet, the Standard tabulates design loading rates for trenches (Table L1, page 145) and for irrigation systems (Table M1, page 160) on what appears to be only a limited soil textural classification, a very imperfect description of soil structure grade and an extensive range of indicative permeability (Ksat) oblivious to the other soil and effluent factors influencing permeability, drainage and capillary movement. Certainly, there is not elaboration on the effects these other factors may have on either increasing or decreasing the design loading rate for the chosen system. It is almost unimaginable that a Council would consider relaxing the values in Table L1 or M1 for a smaller footprint even if the soil conditions warranted a smaller land application area.

That a design loading rate had been tabulated does not appear to have any rationale. That a soil category 3, a loam, high/moderate structure (Table L1, page 145) can have an indicative permeability (Ksat) of 1.5 – 3.0 m/day is discounted into a conservative loading rate of 15 mm/day is unexplained and cannot be deduced from anywhere in the Standard. There is no indication that the 'indicative permeability' rates are anything other than wild guesses from which the long term application rates are an additional guess, then modified by another unknown factor to give a design loading rate. This is real 'smoke and mirrors' stuff!

Further, that the only surface on which the calculation can be made is the bottom area of the trench or bed (L4.1, page 143) does not have any justification when it is clear that both the sidewall and the bottom area contribute to returning the effluent to the hydrologic cycle through their texture and structure. That the water balance (Eqn Q3, page 181) does not have a soil water storage capacity incorporated into a water balance equation is unrealistic.

Surely, the difference between indicative permeability, *based on movement of water, not effluent* (footnote Table 5.1, page 39) and that of typical domestic effluent (whatever that is) does not account for the significant loss of permeability as suggested above, without some technical reference to explain the variation.

From an on-site wastewater consultant's view, to satisfy the Standard, one is required to counter these conflicting statements of fact or fiction to design a system that is likely to be over-designed for the actual site and soil conditions. That much of the Standard is not referenced to actual research, or that research is undisclosed, the arguments outlined above cannot be discussed with the determining authorities; consumers are committed to expensive systems.

**Figure 17 No comment!**

# 7. References

Engle CF, Cogger CG, Stevens RG. Role of soil in groundwater protection. WSU Cooperative Extension Bulletin. Washington State University, Prosser; 1991. Access from https://research.wsulibs.wsu.edu/xmlui/bitstream/handle/2376/6758/eb1633.pdf

Environment Protection Authority Victoria (2016) 891.4: *Code of Practice – onsite wastewater management*, accessed from https://www.epa.vic.gov.au/about-epa/publications/891-4

Geeves, G.W., Craze, B and Hamilton, G.J. (2000) Soil Physical Properties, Chapter 10 in *Soils: Their Properties and Management* Eds. Charman, P.E and Murphy, B.W. Second Edition. Oxford University Press.

National Committee on Soil and Terrain (2009) *The Australian Soil and Land Survey: Field Book. 3rd Edition*. CSIRO Publishing, Collingwood VIC

Northcote, K.H. (1979) *A Factual Key for the Recognition of Australian Soil*. Relim Technical Publications, Adelaide.

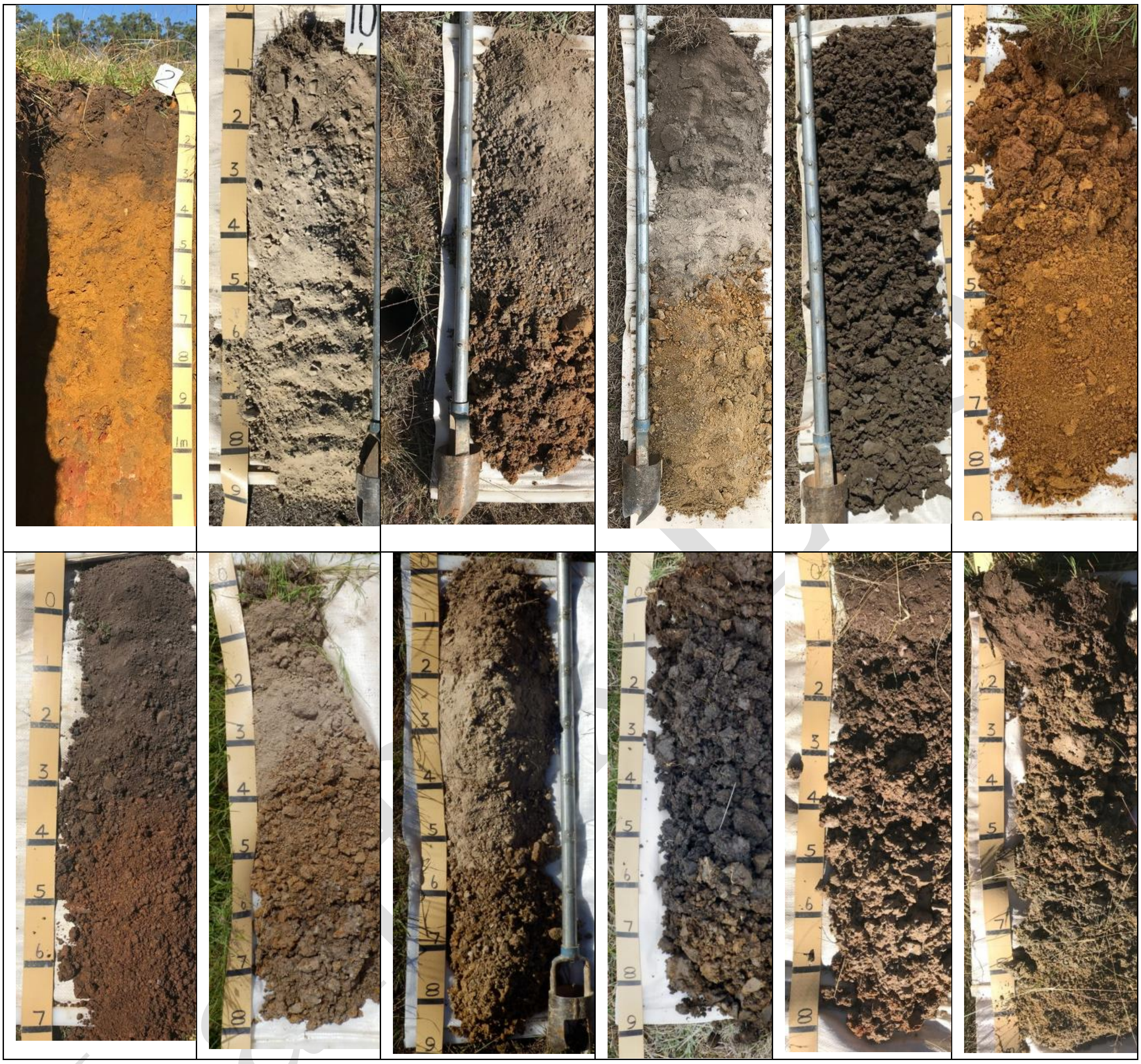
Sheppard, T.G, Ross, C.W., Basher, L.R. and Saggar, S. (2000) *Soil Management Guidelines for Sustainable Cropping* Landcare Crown Research Institute, New Zealand.

Standards Australia and Standards New Zealand (2012) *AS/NZS 1547:2012 On-site domestic wastewater management* Standards Australia Limited, Sydney and Standards New Zealand.

USDA (2017) *Soil Survey Manual*. United States Department of Agriculture, Handbook No.18 Access on 21DEC20, from https://www.iec.cat/mapasols/DocuInteres/PDF/Llibre50.pdf

Victorian Resources Online, accessed from http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_texture_prac

APPENDIX A
A selection of soil profiles examined for on-site wastewater studies



First row - number 1-6 from left
Second row – number 7-12 from left

There has been no attempt to grade the photographs on colour, texture, horizon depth or any other characteristic. The photographs simply illustrate the variability of soil profiles across different geologies and landscape positions.

**Appendix B**
**Classification of field texture grades**

| | Field Texture Grade | | Behaviour of moist bolus | Ribbon (mm) | Approx. clay content % |
|---|---|---|---|---|---|
| | **S** | Sand | coherence nil to very slight, cannot be moulded; sand grains of medium size; single sand grains stick to fingers | nil | < 5% |
| **Cat 1** | **LS** | Loamy sand | slight coherence; sand grains of medium size; can be sheared between thumb and forefinger to give minimal ribbon of about 5 mm | about 5 | about 5% |
| | **CS** | Clayey sand | slight coherence; sand grains of medium size; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain | 5 - 15 | 5% to 10% |
| **Cat 2** | **SL** | Sandy loam | bolus coherent but very sandy to touch; will form ribbon; dominant sand grains of medium size are readily visible | 15 - 25 | 10% to 20% |
| | **FSL** | Fine sandy loam | Bolus coherent; fine sand can be felt and heard when manipulated; will form ribbon; sand grains are clearly visible under s hand lens | 13-25 | 10% to 20% |
| **Cat 3** | **L** | Loam | bolus coherent and rather spongy; smooth feel when manipulated but with no obvious sandiness or "silkiness"; may be somewhat greasy to touch if much organic matter present; | 25 | about 25% |
| | **ZL** | Silty loam | coherent bolus, very smooth to silky when manipulated, will form ribbon | 25 | about 25%, silt 25% |
| **Cat 4** | **SCL** | Sandy clay loam | strongly coherent bolus, sandy to touch; medium size sand grains visible in finer matrix; | 25 - 40 | 20% to 30% |
| | **CL** | Clay loam | coherent plastic bolus, smooth to manipulate; | 40-50 | 30% to 35% |
| | **ZCL** | Silty clay loam | coherent smooth bolus, plastic and silky to touch | 40-50 | 30%-35% clay, silt 25% or more |
| | **FSCL** | Fine sandy clay loam | coherent plastic bolus, fine sand can be felt and heard when manipulated | 40-50 | 30% to 35% |
| | **SC** | Sandy clay | plastic bolus. Fine to medium sand can be seen, felt or heard in clayey matrix | 50-75 | 35% to 40% |
| **Cat 5** | **SiC** | Silty clay | plastic bolus; smooth and silky to manipulate | 50-75 | 30% to 40% clay, silt 25% or more |
| | **LC** | Light clay | plastic bolus; smooth to touch; slight resistance to shearing between thumb and forefinger | 50-75 | 35% to 40% |
| | **LMC** | Light medium clay | plastic bolus; smooth to touch; slight to moderate resistance to ribboning shear | 75 | 40% to 45% |
| **Cat 6** | **MC** | Medium clay | smooth plastic bolus; handles like plasticine and can be moulded into rods without fracture; has moderate resistance to ribboning shear | > 75 | 45% to 55% |
| | **HC** | Heavy clay | smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear | > 75 | 50% + |

**based upon international system, soil sieved < 2mm**

**Source:** McDonald, R.C., Isbell, R.F., Spreight, J.G., Walker, J and Hopkins, M.S. (1990) *Australian Soil and Land Survey: Field Handbook. Second Edition*. Inkata Press, Melbourne. Also Northcote (1979).