Assessing your Soil Resources for Irrigation

WISE **WATERING**
Irrigation Management Course

These materials are part of the Wise Watering Irrigation Management Program, developed in part from the NSW Agriculture WaterWise on the farm education program and The Mallee Wells Irrigators manual.

Course development and presentation by Davey & Maynard, in association with Armstrong Agricultural Services, Serve-Ag, Hinton Agricultural Consulting, Rural Development Services and the Tasmanian Department of Primary Industries, Water and Environment.

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Introduction

The most important functions of your soil are to store moisture and nutrients and to supply these to plants between rainfall or irrigation events. How much water the soil can store can vary greatly within very short horizontal and vertical distances.

With the skills learned in this workshop you will be able to conduct your own soil evaluations, and use the results in the operation of your irrigation program .

This workshop will give you definitions of the soil characteristics that are of greatest importance for irrigation, will help you understand the impacts these differences in soil characteristics have on irrigation management.

The workshop also describes the main soil types found in the cropping areas of Tasmania, and their characteristics.

Learning outcomes

When you have completed this workshop you will be able to:

- define the terms field capacity, refill point, permanent wilting point and readily available water (RAW)
- identify soil layers
- identify the effective rootzone
- identify soil textures
- calculate the soil's readily available water (RAW), which indicates how much water is available to the plant
- discuss how water is held by soil
- assess the suitability of soil for irrigation

To achieve these outcomes, the workshop activities include:

- hand texturing soils
- completing calculations on rootzone RAWs

Additional reading

Bill Chilvers, DPIWE, 1996. "Managing Tasmania's Cropping Soils".

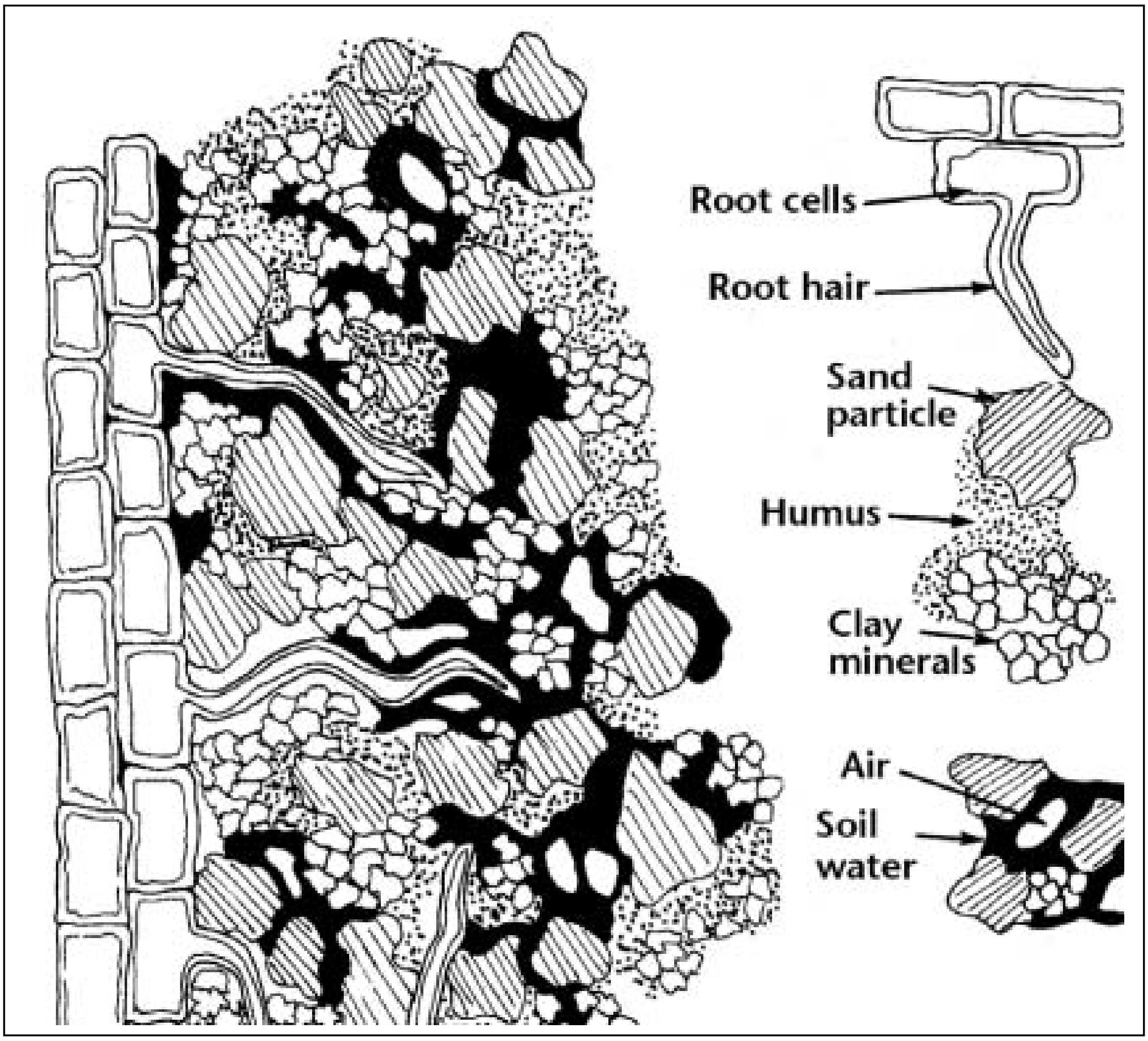
What is soil?

Soil consists of five components:

- mineral particles derived from weathered ‘parent’ rocks
- humus (organic matter), the remains of plants and animals
- water containing dissolved nutrients
- air supplying oxygen to plants
- living organisms including bacteria, fungi, worms etc.

The amount of each component varies with the soil type and depth from the surface.

Figure 1. Major soil components



Mineral particles

The mineral particles of the soil come from the breakdown of rocks. They vary in shape and size and are broadly divided into three categories:

SAND	the largest soil particles	(0.02 to 2 mm)
SILT	smaller particles of parent rock	(0.002 to 0.02 mm)
CLAY	very small particles of parent rock, important in soil structure and fertility (less than 0.002 mm)	

Sand and silt particles are often bound together by clay and organic matter. In the pore spaces between these mineral particles are water, air, organic matter and micro-organisms.

The type and amount of mineral particles varies greatly between soils, resulting in a large number of soil types.
Texture is the relative amount of sand, silt, clay and organic matter in the soil. For example, a sandy loam has a greater amount of sand than other components, while a heavy clay is predominantly composed of clay particles.

Figure 2. The soil texture triangle

Soil structure describes how the mineral particles and organic matter are arranged to form aggregates, as well as how pore spaces are arranged within and between aggregates. Soils with good structure hold more water that available for plant use than those with poor structure.

Knowing how much water your soil can hold makes irrigation planning easier and can improve water use efficiency. If you can minimise the time that soil is too dry or too wet, the benefits of the organic matter and nutrients in the soil and the activity of the living organisms in it, can be maximised. Organic matter and living organisms are essential for good soil health, fertility and structure.

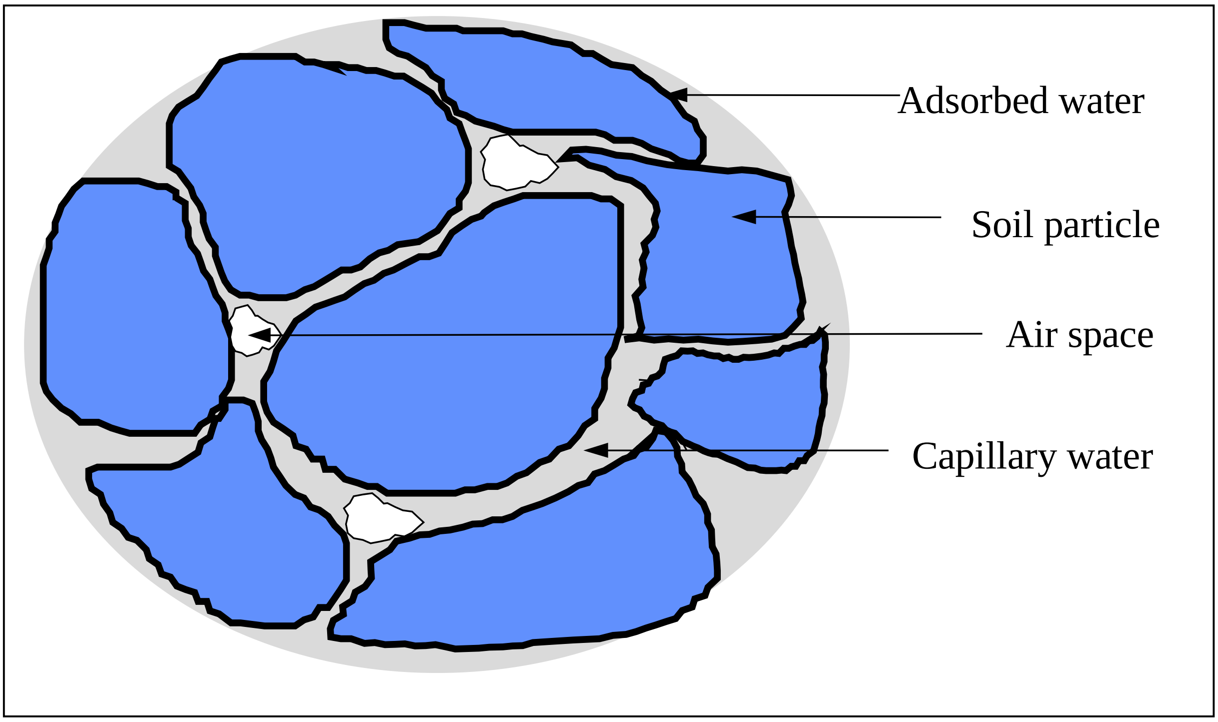
Soil water

Soil is like a big sponge—it can only soak up a certain amount of water and it can only do it at a certain rate (see infiltration rates later). When soil is saturated there is no benefit in applying more water. Excess water only produces plant stress, waterlogging, drainage to watertables below the rootzone, run-off and leaching of fertilisers.

Soil water is held in soil pores (the spaces between soil particles). There are two forms of soil water (Figure 3):

- water held tightly to the soil particles (adsorbed water)
- water held in the pores between the soil particles (capillary water)

Figure 3. The two forms of soil water (microscopic view)



Roots remove water from the soil pores by creating a suction.

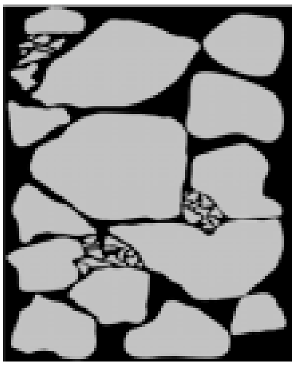
Plants use water from large soil pores first because it is more difficult for the roots to remove water held by the small soil pores. Some plants can extract water from drier soil more easily than others.

As efficient irrigators we should aim to minimise the time soil is in a saturated or dry state, and maximise the time when water is readily available to the plant.

Describing soil water content

How 'tightly' the soil holds onto its water, and how much effort the plant has to exert to extract this water, can be described as 'soil moisture tension'. We use a negative pressure in kPa to describe this tension. By measuring soil water, we can describe the condition of the soil at each stage of irrigation and crop use: from 'saturation point' to 'permanent wilting point', and the stages in between: 'field capacity' and 'refill point'.

Saturation point



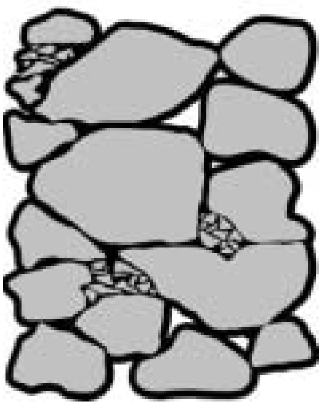
After heavy rain or over-irrigation, soil may become saturated. This is when even the largest pores are filled with water (figure 4). Applying more water causes ponding, run-off or deep drainage.

When the soil is saturated there is no air for the plant roots. This will stress most actively growing plants.

Figure 4. Saturated soil

The total water-holding capacity of saturated soils is generally from 400 to 600 mm of water per metre of soil depth but a much smaller amount is actually able to be used by the plant. This is because as the plant draws on this water the tension increases and eventually a point is reached when the tension is too high for the plant.

Field capacity



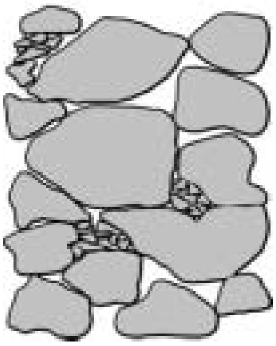
Once rain or irrigation stops, large soil pores (macropores) drain due to gravity. Depending on the type of soil, this drainage may take 1–4 days.

When the large pores have drained, the soil is still wet, but not saturated. The soil is at field capacity (figure 5). (Field capacity in most soils is at a soil-water tension of about –8 to -10 kPa.)

Figure 5. Soil at field capacity

The small pores resist gravity and hold onto their water through capillary force. The water they provide is the main source of readily available water for the plant. It is easy for plants to extract water when the soil is at or near field capacity.

Permanent wilting point



As water is used by a plant, and evaporation also takes place, the plant has to work harder to extract water from the soil. The harder the plant has to work, the higher the soil water tension. If a plant has to work too hard, it will start to wilt, reducing growth and yield.

Eventually the soil reaches a point when the plant can no longer extract any water. This is called **the permanent wilting point** (figure 6). Once the soil has passed this point, water is held by the soil so tightly that the plant will be dead from lack of water.

Figure 6. Soil at permanent wilting point

Figure 7. The composition of a sandy loam soil at Field Capacity.

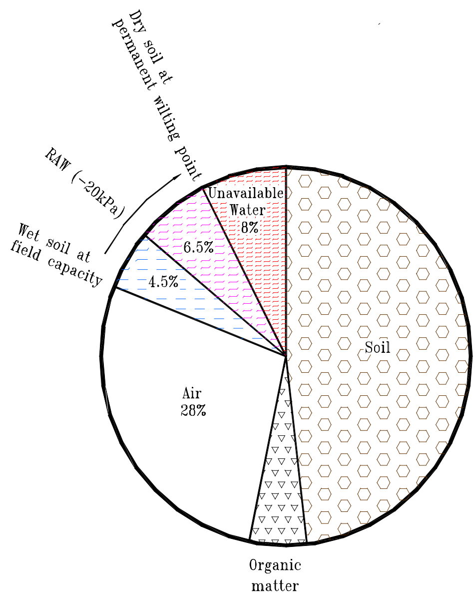
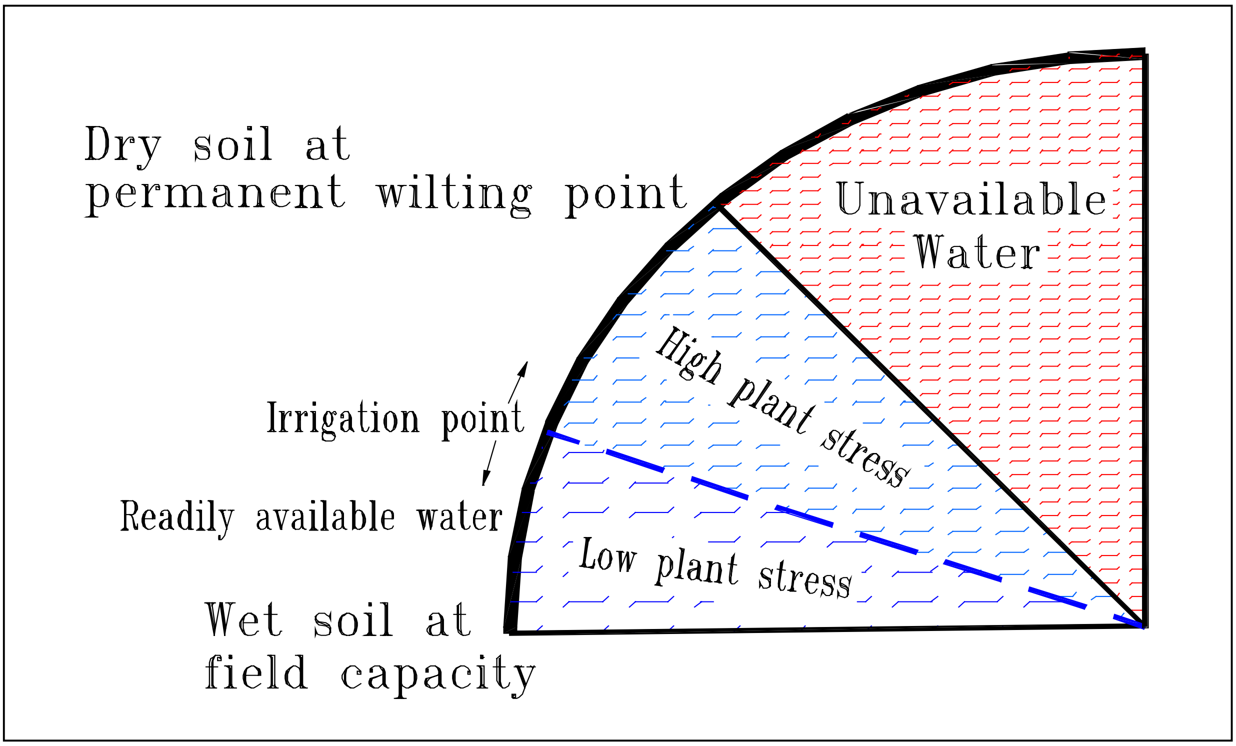


Figure 8. The availability of water in the soil

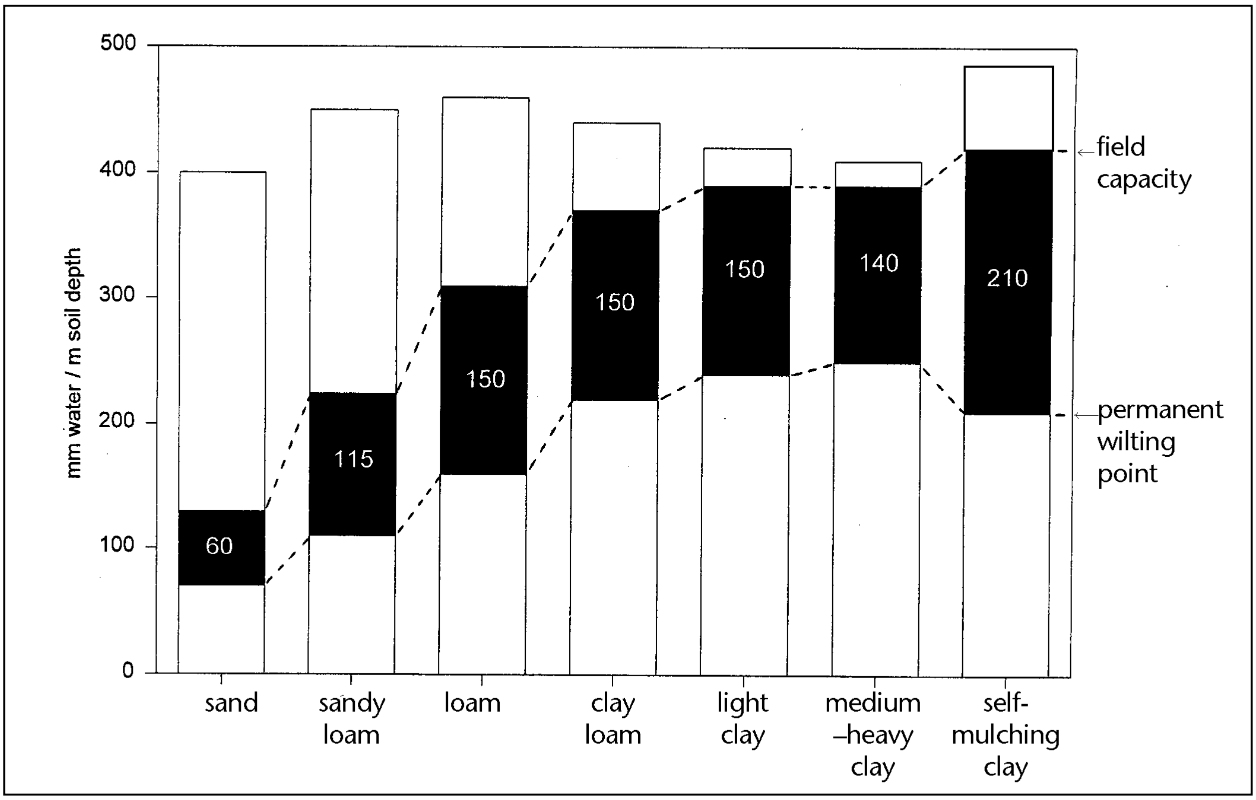


The dotted line (Irrigation Point, or Refill Point) represents the point when irrigation is applied to re-wet the soil to field capacity. Readily Available Water is water that can be used by the crop between field capacity and the Refill Point. Changing the Refill Point to wetter or drier soil conditions can control the degree of plant stress.

Total water-holding capacity of soil

As stated earlier, the total water-holding capacity of saturated soils is generally 400–600 mm of water per metre of soil depth, but this depends very greatly on the soil texture.

Figure 9. The levels of soil water in 1 metre of soil of various textures.



For example:

- Sand (S) holds about 70 mm of water per metre of soil depth below permanent wilting point, 60 mm (the shaded section) is the total water available to plants (Available Water), and the remaining 270 mm is the free-draining water between field capacity and saturation.

- Medium to heavy clay (MC–HC) holds slightly more water, but 250 mm is held below permanent wilting point, 140 mm is available to plants, and only about 20 mm is free-draining above field capacity.

- Sandy loams (SL), loams (L), clay loams (CL) and self-mulching clays (SMC) hold a similar total volume of water. Self-mulching clays have the most total available water which plants can use, followed by the loams, clay loams and light clays (LC).

Readily Available Soil Water

A plant cannot use all of the water held in the soil. For practical irrigation planning irrigators must work with the water that can be readily removed from the soil by the plant, the readily available water, or RAW.

RAW is expressed in millimetres per metre (mm/m) and indicates the depth of water (mm) held in every metre (m) of soil depth that can be readily removed by the plant. RAW can be calculated for the total profile depth, or more usefully just down to the depth of the plant's effective rootzone. (In the examples later we work out RAW for the full soil profile and the effective rootzone of a particular crop.)

To achieve high yields without creating excess drainage you need to know the RAW for each crop or each planting.

Only 15 to 50% of the Available Water is "Readily Available Water" (RAW); when this is used irrigation should be applied.

TABLE 1: Readily Available Water for a range of soil textures
(data from Bill Cotching, Tas. DPIWE)

Soil texture	RAW (Readily Available Water (mm/m))
Sand	30
Loamy sand	50
Sandy loam	70
Sandy loam rich in Organic Matter	90
Loam	90
Clay	50
Clay loam (Krasnozem)	80
Well structured clay	60

Effective Rootzone

The effective rootzone is that part of the plant's rootzone where the main mass of a plant's roots that contribute to crop growth are found. Below the effective rootzone there may be a few roots, but any water they extract is not significant for the plant's growth.

The effective rootzone is typically two-thirds the depth of the deepest roots. Some crops, such as irrigated pasture and grass seed crops develop a mass of shallow roots with only a few roots penetrating into deeper soil layers (see figure 8). When calculating the RAW for these crops it is important to only use a shallow depth as the effective rootzone.

For annual crops, the root zone increases during the irrigation season. The following table indicates the depth of the root zone for commonly irrigated annual and perennial crops.

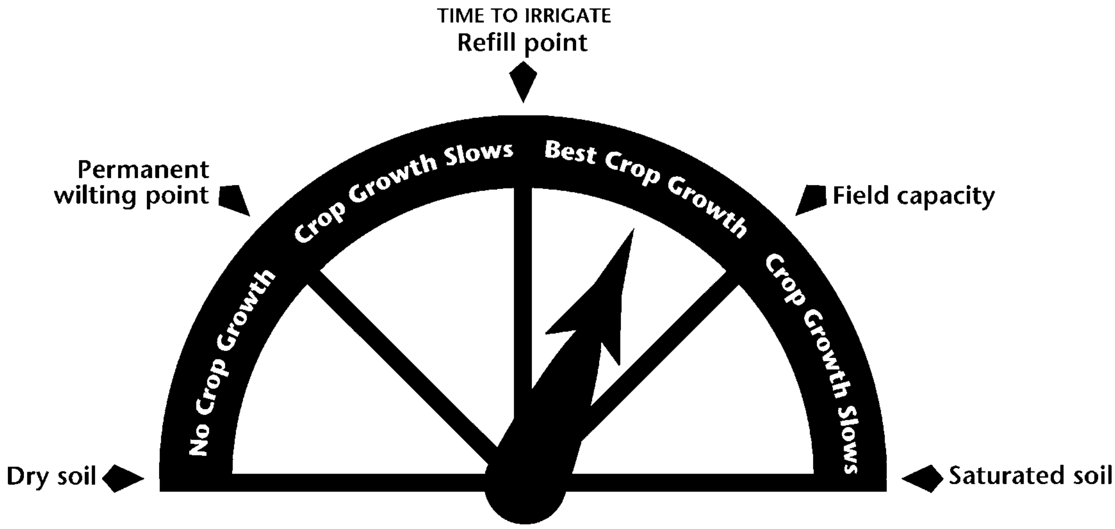
TABLE 2. Rootzone depths for a range of Tasmanian crops.

Crop	Nominal depth of the rootzone when crops are fully developed (metres)
Potatoes	0.6
Poppies	0.5
Peas	0.5
Green Beans	0.5
Pyrethrum	0.8
Buckwheat	0.4
Carrots	0.5
Onions	0.3
Broccoli	0.
Squash	0.5
Lucerne	1.2
Pasture	0.3
Stone/pome fruit – mature trees	1.0
Vines	0.7

When to irrigate (Refill Point)

After Readily Available Water (RAW) has been used, plant roots cannot as easily extract water from the soil. This point is referred to as the refill point. As its name suggests, Refill Point is the time to irrigate. The drier the soil is, the more water it needs to return to field capacity.

Figure 10. Different levels of soil moisture



Calculating RAW

The only way to determine the RAW for a particular situation is to go out and dig some holes and get your hands dirty.

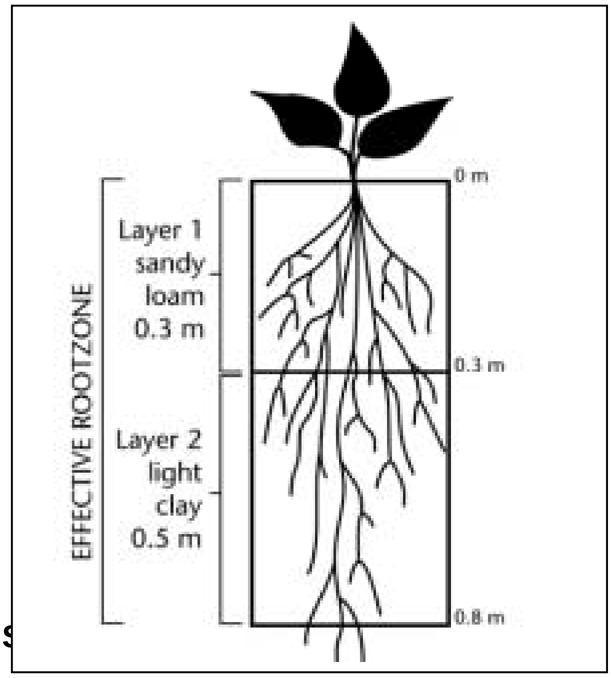
The RAW stored within the effective rootzone can be calculated by measuring the thickness of each soil layer (in metres or parts of a metre), and determining its soil texture, and then multiplying the thickness by the appropriate RAW value as shown in table 1.

The soil profile usually shows a change in texture, generally becoming more clayey with depth. Of these lower layers are considered part of the rootzone, then the RAW levels for these subsoil layers become important.

The steps involved in calculating RAW are:

Step 1 Identify the depth of the effective rootzone.
Step 2 Identify and measure the thickness of the different soil layers within the effective root zone.
Step 3 Determine the soil texture of each layer.
Step 4 Identify the RAW value for each soil layer from table 1.
Step 5 Multiply the thickness of each soil layer by its RAW value.
Step 6 Add up the results of step 5 for each soil layer to obtain the rootzone RAW.

Calculating rootzone RAW: example 1



A plant is growing in 0.3 m of sandy loam over 0.5 m of clay. For a soil pit at this site the calculations would be:

Effective rootzone = 0.8 m
(In this simple example, the effective rootzone is the top 0.8 m of the soil profile where roots are found.)

Step 2: Identify and measure the soil layers within this 0.8m.
Layer 1: 0.3 m
Layer 2: 0.5 m

Step 3: Determine the soil texture of each layer.
Layer 1: sandy loam
Layer 2: clay

Step 4: Using table 1, identify the RAW for each soil layer.
RAW values for each layer are:
sandy loam= 50 mm/m
clay = 40 mm/m

Step 5: Multiply the thickness of each soil layer by its RAW value.
Layer 1: 0.3 m x 50 mm/m = 15 mm
Layer 2: 0.5 m x 40 mm/m = 20 mm

Step 6: Add up the results of step 5 to obtain the total RAW stored within the crop's effective rootzone.

Total RAW = 15 mm + 20 mm = 35 mm

Calculating rootzone RAW: example 2

Assuming a mature lucerne stand on a Krasnozem soil type.

Depth (m)	Texture	RAW, mm/m	RAW for the soil layer, mm
0-0.4	Clay Loam	70	28
0.4-1	Medium Clay	70	42
Total RAW for the rootzone			**70**

The field capacity and refill point values are critical for the correct use of many of the soil water monitoring technologies. These values vary according to soil type and crop grown. Examples of values used successfully over past seasons in Tasmania are presented in table 3.

Table 3. Field capacity and refill point for Tasmanian soils

Soil type	Crop	Field capacity (mm)	Refill point (mm)	Tensiometer reading at 30 cm depth (kPa)
Red ferrosol (Krasnozem)	Potatoes, poppies, peas, etc	40	30	40
Red ferrosol (Krasnozem)	Pyrethrum	40	25	60
Duplex soil (Sandy loam topsoil)		28	18	35
Deep sand	Potatoes	24	14	25
Cressy soil	Potatoes	40	30	40
Black cracking clay	Poppies	45	35	45

Assessing soil texture

The amount of water held by the soil and available to plants varies with the individual soil type. As we discussed earlier, soil type depends on the relative proportions of sand, silt and clay.

Texture is assessed in the field by the feel of a sample of moist soil when worked between the finger and thumb. The ribbon test uses thumb pressure against the middle joint of the index finger to produce a ribbon about 2 mm thick.

The soil must be moist (near field capacity) and pliable. The feel and behaviour of the soil as you moisten and knead it will assist you in identifying the soil texture.

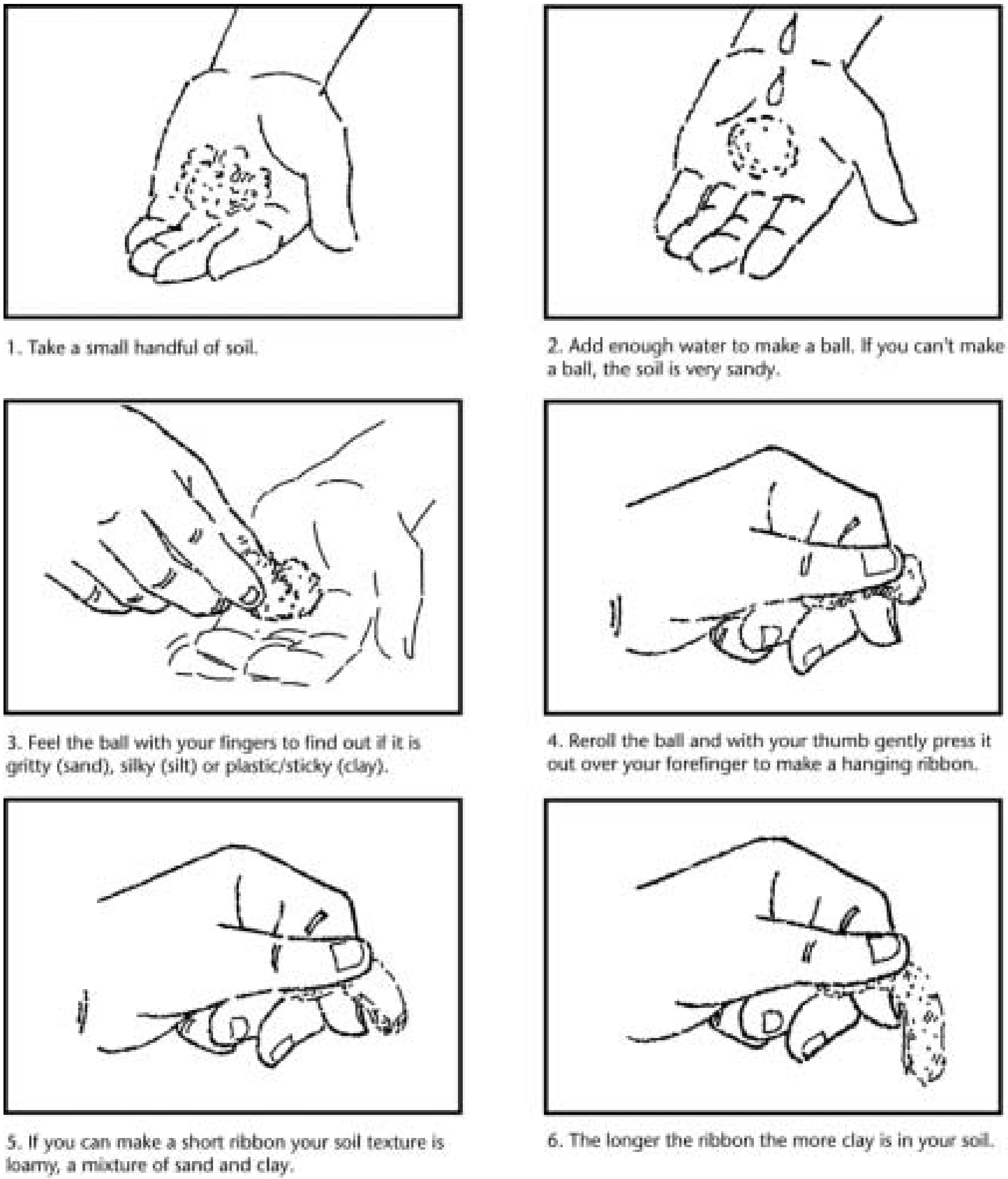
Scan through table 4 so you have an idea of how the soil will behave and feel as you are assessing your soil texture.

TABLE 4. Guide to soil textures

SOIL TEXTURE	RIBBON LENGTH	HOW THE SOIL BEHAVES/FEELS	% clay
Sand (S)	nil	Coherence nil to very slight, cannot be moulded; sand grains adhere to fingers.	less than 5%
Loamy sand (LS)	5 mm	Slight coherence; sand grains of medium size; can be sheared between thumb and forefinger.	5–10%
Clayey sand (CS)	5–15 mm	Slight coherence, sticky when wet, many sand grains stick to fingers, discolours fingers with clay. Little or no organic matter.	5–10%
Sandy loam (SL)	15–25 mm	Coherent bolus but very sandy to the touch; dominant sand grains are of medium size and readily visible.	10–20%
Light sandy clay loam (LSCL)	20–25 mm	Coherent bolus, sandy to the touch; dominant sand grains are of medium size and readily visible.	15–20%
Loam (L)	about 25 mm	Loams can form a thick ribbon. Soil ball is easy to manipulate and has smooth spongy feel with no obvious sandiness. Greasy to touch if organic matter present.	about 25%
Sandy clay loam (SCL)	25–40 mm	Strongly coherent bolus, sandy to touch; medium sand grains visible in a finer matrix.	20–30%
Clay loam (CL)	40–50 mm	Strongly coherent and plastic bolus, smooth to manipulate and slightly sticky.	30–35%
Sandy clay (SC)	50–75 mm	Plastic sticky bolus, fine to medium sand grains can be seen and felt.	35–40%
Light clay (LC)	50–75 mm	Plastic behaviour evident, smooth feel easily worked, moulded and rolled into rod. Rod forms a ring without cracking.	35–40 %
Light medium clay (LMC)	75–85 mm	Plastic bolus; smooth to touch; slight to moderate resistance to ribboning shearing.	40–45%
Medium clay (MC)	greater than 75 mm	Smooth plastic bolus; handles like plasticine; can be moulded into rods without cracking; resistant to shearing and sticks to thumb and forefinger.	45–55%
Heavy clay (HC)	greater than 75 mm	Smooth, very plastic bolus; firm resistance to shearing; will mould into rods. Handles like stiff plasticine. Very sticky and strongly coherent. Rods will form a ring without cracking.	over 50%

Assess the texture of several soil types by hand texturing them.

Figure 11. Instructions for determining soil texture.



1. Take a small handful of soil.

2. Add enough water to make a ball. If you can't make a ball, the soil is very sandy.

3. Feel the ball with your fingers to find out if it is gritty (sand), silky (silt) or plastic/sticky (clay).

4. Reroll the ball and with your thumb gently press it out over your forefinger to make a hanging ribbon.

5. If you can make a short ribbon your soil texture is loamy, a mixture of sand and clay.

6. The longer the ribbon the more clay is in your soil.

Commonly irrigated Tasmanian soils

There are five main soil types that represent the major irrigated soils in Tasmania: Burnie (red ferrosols – basalt soils, ie., Krasnozems); Cressy clay loams (dermosols); duplex soils (sodosols – sandy loam over clay), deep sandy soils (tenosols) and the black cracking clays (vertosols).

The identification of which soil type is being irrigated can be used in the management of irrigation timing, frequency and quantity. Early identification of soil type in the planning of irrigation will allow for identification of field capacity and refill points as presented in this manual and identification of management factors that need to be considered under irrigated agriculture.

Burnie soils are deep, heavy textured soils formed on basalt with characteristic red colouring because they contain high levels of iron oxides.

These soils have
- strongly developed structure
- no limiting layers to root growth
- will suffer compaction if cultivated or trafficked when wet
- are susceptible to erosion on slopes, and
- are well drained.

Cressy clay loams are heavy textured soils with friable subsoils overlying brightly coloured mottled heavy clay formed on sediments in the Cressy to Hagley district.

These soils have
- restricted drainage
- respond to artificial drainage (pipes and moles)
- will suffer compaction if cultivated or trafficked when wet
- often have ironstone just below the topsoil, and
- have restricted root growth due to subsoil saturation.

Duplex soils (sandy loam over clay) have a strong texture contrast between the topsoil and subsoil. They are formed on sediments or sedimentary rocks and are one of the dominant soil types used for agriculture in Tasmania.

These soils have
- restricted drainage resulting in waterlogging
- variable topsoil depth within paddocks
- are susceptible to wind erosion, and
- have restricted root growth.

Deep sandy soils are developed on wind blown sands of varying thickness.

These soils have rapid drainage
no layers restricting root growth, and
are susceptible to wind erosion.

Some areas have high ground water tables, which restrict root growth.

Black cracking clays are black, self mulching heavy textured soils developed on river sediments or volcanic rocks.

These soils have slow drainage
are very susceptible to compaction if worked wet, and
have restricted root growth.

Water infiltration into soil

Water can only infiltrate into the soil at a certain rate, and the longer water is applied the slower this rate becomes. The rate that water can enter the soil is called the **infiltration rate** of a soil.

* With pressurised irrigation systems the rate at which you apply water must not exceed the soil's infiltration rate.

* With surface systems the application at any one point must be long enough to allow enough water to enter the soil profile.

Exceeding the infiltration rate can (depending on the situation) result in soil damage and run-off. It can also cause erosion, loss of fertilisers, and excessive waterlogging of the root zone in low-lying areas.

Infiltration rates can vary within a field as well as between fields. Infiltration mainly depends on soil texture, structure, porosity and bulk density, but groundcover, slope and dispersion also influence it.

Infiltration rate usually decreases with soil depth so application rates may need to be adjusted if the water movement through the subsoil is slower than through the topsoil. Table 5 shows the range expected for the six main texture classes.

TABLE 5. Average infiltration rates for some soil types

Texture group	**Suggested application rate (mm/h)**		**Infiltration rate range (mm/h)**
	Average soil structure	**Well-structured soil**	
Sands	50		20-250
Sandy loam	20	45	10-80
Loam	20	45	1-20
Clay loam	20	40	2-15
Light clay	2	5	0.3-5
Medium-heavy clay	0.5	5	0.1–8

Adapted from Charman, P.E.V. and B. W. Murphy (eds) 2000, Soils: their Properties and Management, in association with the NSW Department of Land and Water Conservation, 2nd edn, Oxford University Press, Melbourne and the "Environmental Guidelines for the use of Recycled Water in Tasmania" (draft 8, April 2000).

Figure 12. Cumulative infiltration of water

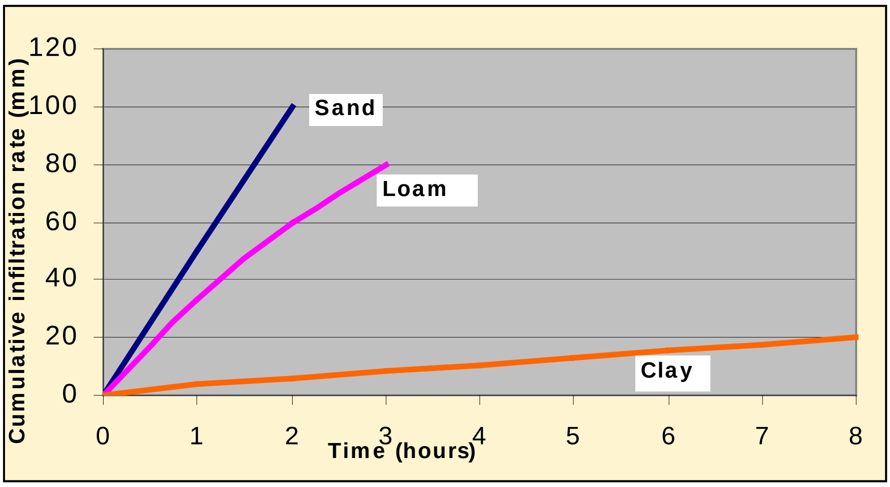


Figure 12 illustrates how water infiltrates into different soils over time.

For example, if 30 mm/h is being applied to a loam (see table 3), and the application continues for 3 hours, the total amount applied would be 90 mm. This is above the cumulative rate for loam (~80 mm), so run-off will occur.

Application rates can safely be increased if:

soil is well structured (especially red ferrosols and self-mulching clays)

soil aggregates are stable when wet
soil is resistant to erosion

moderate soil salinity is present (where structure is improved by the flocculating effect of salinity)

Application rates should be reduced if:

soil has weak or unstable structure (including single grain size and massive structure)
soil is bare

slope is more than 5% (a commonly used maximum infiltration rate on steeper slopes is 10 mm/h)

soil is sodic (above ESP 6%)

The infiltration rate of a soil may be increased by management techniques such as:

- opening up the surface (breaking up crusts, hardpans and hard-setting layers, adding gypsum to sodic soils)
- relieving compaction (cultivating, coring, spiking, splitting)
- improve soil structure (increasing organic matter, including a pasture phase in rotation, growing deep-rooting plants such as lucerne)
- breaking up impermeable layers by subsoil cultivation if appropriate
- retaining more surface cover (stubbles, pastures)
- overcoming water repellency by the methods above, especially organic matter in the topsoil

Soils within each texture class which have good soil structure are able to hold more RAW than those with poor to moderate structure. The figures in table 3 (Tasmanian Soils RAW figures) are therefore low for soils which are naturally well-structured (such as self-mulching clays) or where structure is good due to high organic matter content.

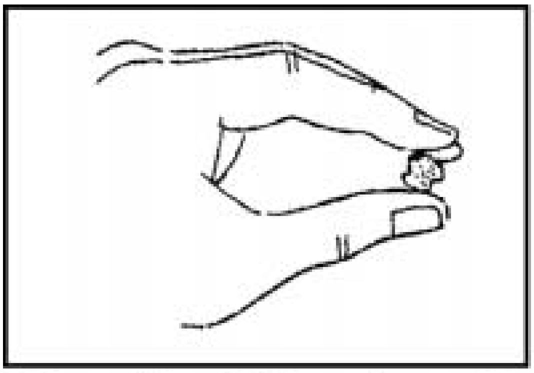
Testing for slaking

Slaking and dispersion describe processes where soil structure breaks down. If a soil is not stable, it slakes and disperses quickly when it is wet.

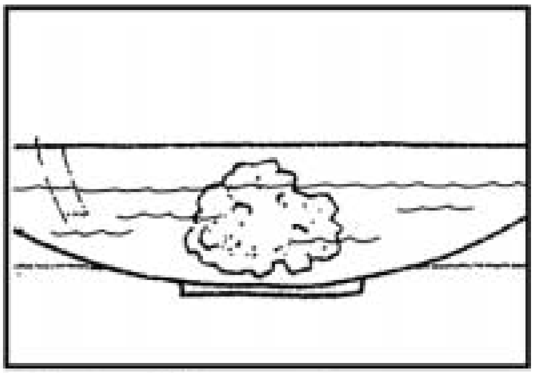
Slaking is the breakdown of aggregates into smaller aggregates as air in the soil pores is forced out by water. Slaking is commonly caused by over-cultivation or occurs in soil with little organic matter.

Soils that slake form hard-setting layers or crusts at the surface when they dry out. Slaking can be reduced by increasing the organic matter content of a soil, as this helps to form more aggregates which are stable when wet.

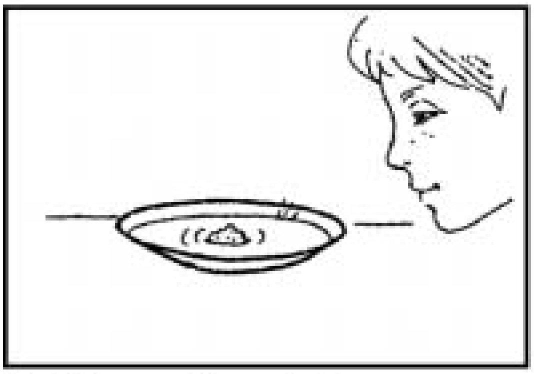
Figure 13. Testing soil for slaking.



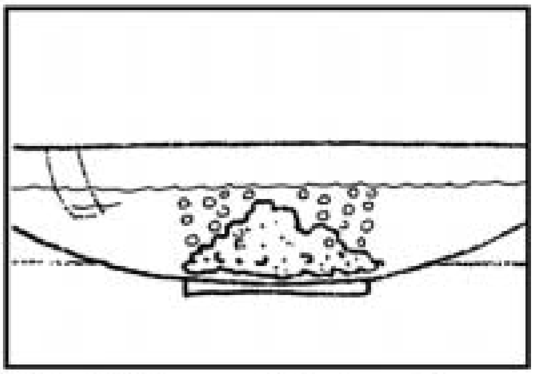
1. Take a small lump of soil, about as big as a marble.



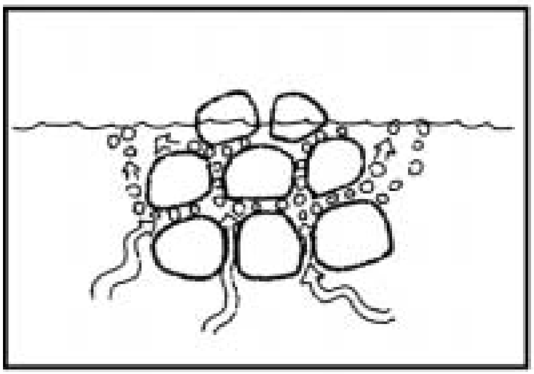
2. Place it carefully in a saucer of water.



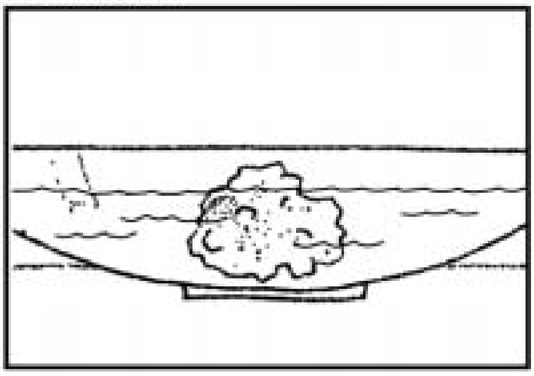
3. Watch to see whether anything happens.



4. If small bubbles appear in the water, and the lump collapses, your soil has slaked. It has no humus or decaying organic matter to hold the soil particles together.



5. When soil slakes, water rushes into the air spaces in the soil, forces the air out (as bubbles) and explodes the soil particles. Slaking occurs when soil is cultivated without any organic matter going into the soil.



6. If nothing happens to your soil lump, it has enough organic matter in it to hold it together. It has good structure.

Testing for sodicity and dispersion

Sodicity

If a soil is ‘sodic’ it means the soil has a high number of clay particles that are held together by sodium ions. In these circumstances the clay behaves in a different way to clays with a higher proportion of calcium ions, and sodic soils will easily breakdown and disperse on wetting. Soils with exchangeable sodium above 6% of total exchangeable bases are called ‘sodic’ and are dispersive.

A way of reducing sodicity is to replace the sodium with calcium, commonly applied as gypsum. The gypsum forms a stronger bond between the clay particles, making them less susceptible to dispersion.

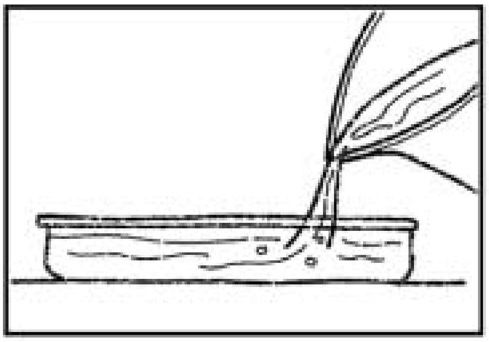
Other possible solutions are to alter farming practices to retain organic matter in the topsoil and to use non-inversion tillage to prevent the more sodic subsoils from being brought to the surface.

Dispersion

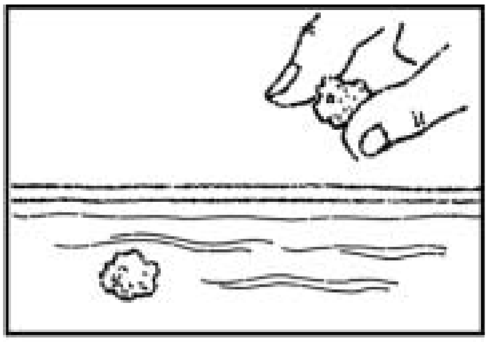
Dispersion is when soil breaks down into individual particles of sand, silt and clay when wet. A dispersive soil is structurally unstable and forms crusts when it dries. In dispersive subsoils the clay particles clog pore spaces, forming a barrier to water and air movement, and to root growth.

Highly dispersive soils erode easily, are likely to cause problems of poor seedling emergence and workability and do not respond to installation of artificial subsoil drainage.

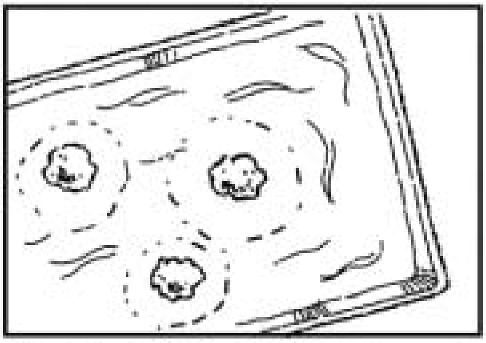
Figure 14. Testing soil samples for dispersion



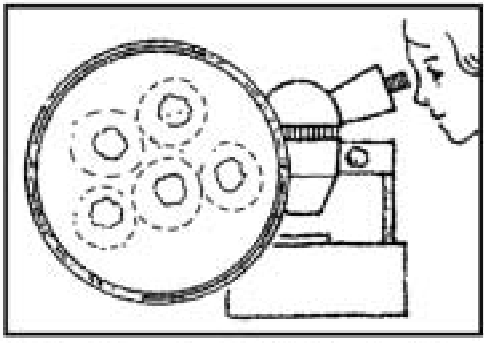
1. Pour some rainwater or distilled water into a dish placed where it will not be disturbed for several hours. (Do not use town water.)



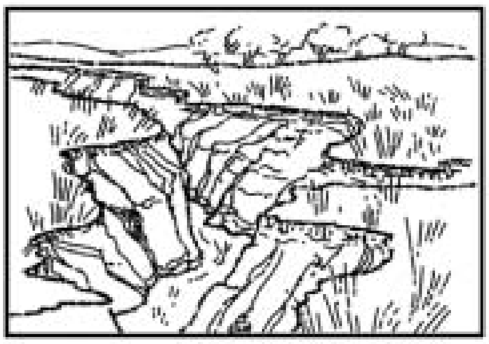
2. Drop several small lumps of dry soil into the water one at a time.



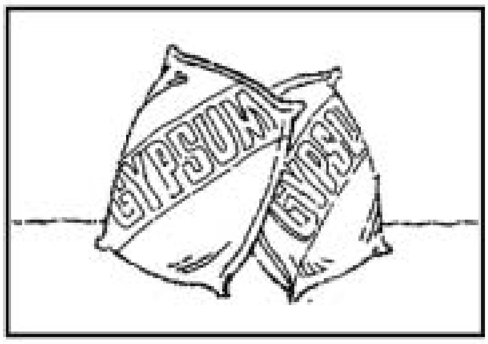
3. Check after 10 minutes whether the water around the soil has started to go cloudy. If it has, this means that the soil has started to disperse, and possibly indicates that the soil is sodic. Look again after 30 minutes, and again after 2 hours, to further check for cloudiness around the soil.



4. Sodic soil has sodium attached to the clay. When the clay is wet, the sodium attracts a water shell around each clay particle, preventing the particles from joining together. The separated (dispersed) clay particles make water look muddy or cloudy.



5. Sodic soil is a problem because it erodes easily. The individual clay particles are easily washed away by water, leaving huge gullies. The eroded particles settle into a hardsetting, crusted topsoil. It is difficult for water, air or plant roots to move through it. Slow water infiltration is a major problem in sodic soils.



4. Gypsum can help manage sodic soils in two ways. In the short term it provides a moderately saline soil solution which prevents dispersion. In the long term, the sodium in the clay is replaced with calcium from the gypsum. The calcium makes the soils less likely to separate into individual particles.

Testing for soil salinity

Salts occur naturally in the environment. All water has some salt in it, and as plants use water from the soil, the salt is left. In areas where evaporation greatly exceeds rainfall it is likely that there will be a build-up of salt: in these cases, additional irrigation water (a leaching fraction) may be required to flush excessive salts and maintain the level below that harmful to plants.

In Tasmania, leaching by winter rainfall will normally reduce soil salinity to manageable levels. But it is important to know what happens to this salt.

The prime concern is that irrigation may lead to more water seeping to the watertable. As the watertable rises, saline groundwater moves closer to the rootzone and the soil surface causing both waterlogging and salinity.

Depending on the soil type, if groundwater is within 2 metres of the surface, capillary action will result in the plant using the groundwater, and the salt level in this water will then build up. In such cases it is important to reduce the groundwater level.

Soil salinity can be measured using a simple field test. This gives an indication of the salts in the soil of your farm. The test is reasonably accurate in indicating if salts may cause yield losses or soil problems, but, to be certain, we strongly recommend that you send soil samples away for laboratory testing.

What you need to test for salinity:

- a sample of soil from the rootzone of your crop or pasture. Dig a hole and take a sample from a depth of 100 to 300 mm. Store the sample in a plastic bag.
- If you have time (especially if sampling from near trees or in a deep-rooted pasture), take an additional sample from below 300 mm. Salinity tends to increase with depth (surface salts are flushed down by rainfall or irrigation, and brought up from below by rising groundwater).
- a set of scales
- a screw-top jar or container
- rainwater or distilled water
- a liquid-measuring container, and
- a salinity (conductivity) meter.

What you do:

1. Take a soil sample and leave it to dry as long as possible. (Leave the sample bag open to let moisture escape.)

2. Crush the air-dried sample so there are no large aggregates (clods of soil). You may need to crush these aggregates with a stone or hammer. Soil particles should be no larger than 2 mm. Remove as much foreign matter, plant material and stones from the sample as you can.

3. Add five parts of rainwater or distilled water to every one part of soil. So, if you put 50 g of soil (weighed on scales) into the container, then you need to add 250 mL of the rainwater or distilled water.

4. Shake the container vigorously for three minutes to make sure the salts dissolve. In clay loam to clay soils, more shaking (for one minute every three minutes, repeated three times) brings more salts into the solution and increases the accuracy of the test.

5. Allow the solution to settle for at least one minute before testing.

6. Place the salinity meter in the solution (but not in the soil at the bottom of the jar), and read the display once it has stabilised.

7. Wash the meter electrodes and sample jar with distilled water or rainwater, and dry.

8. Convert your salinity meter readings to soil salinity (EC_{se}) by finding the soil sample texture in Table 6 and multiplying by the value of the conversion factor given. For example, if your soil is a clay loam with a meter reading of 0.5 dS/m, multiply 0.5 by 8.6. The resulting value of 4.3 dS/m is an approximate value for the salinity of the soil (EC_{se}).

TABLE 6. Soil salinity conversion factors (see Saltpak Manual)

Soil texture	% Clay (approx.)	Conversion Factor	
		Surface soil (top 15 cm)	Subsoil (below 15 cm)
Sand	<10%	14	17
Loam	25-30%	12	15
Light clay	35-40%	11	13
Heavy clay	50-60%	6	8
Very heavy clay	>60%	4	5

Interpreting Ec_{se}

It is accepted practice that saline soils are those which have an EC_{se} of more than 2 dS/m. If your EC_{se} is more than 2 dS/m, seek expert advice on the suitability of your soil for the crops and pastures you want to grow, and for management options to reduce soil salinity.

Lower levels of salinity can affect the growth and yields of salt-sensitive plants such as most legumes (clovers, beans and peas), maize and many horticultural crops. If your EC_e is 1 to 2 dS/m, and you intend to grow any of these crops, you should also seek expert advice.

Impacts of irrigation on soils

Irrigation impacts on soils in two ways;

- Directly, through changing the water and chemical balance (particularly salt balance), and,

- Indirectly, for example the impacts of cultivation associated with annual cropping.

Assessing Salinity Risk for Irrigation Developments and Land use Change

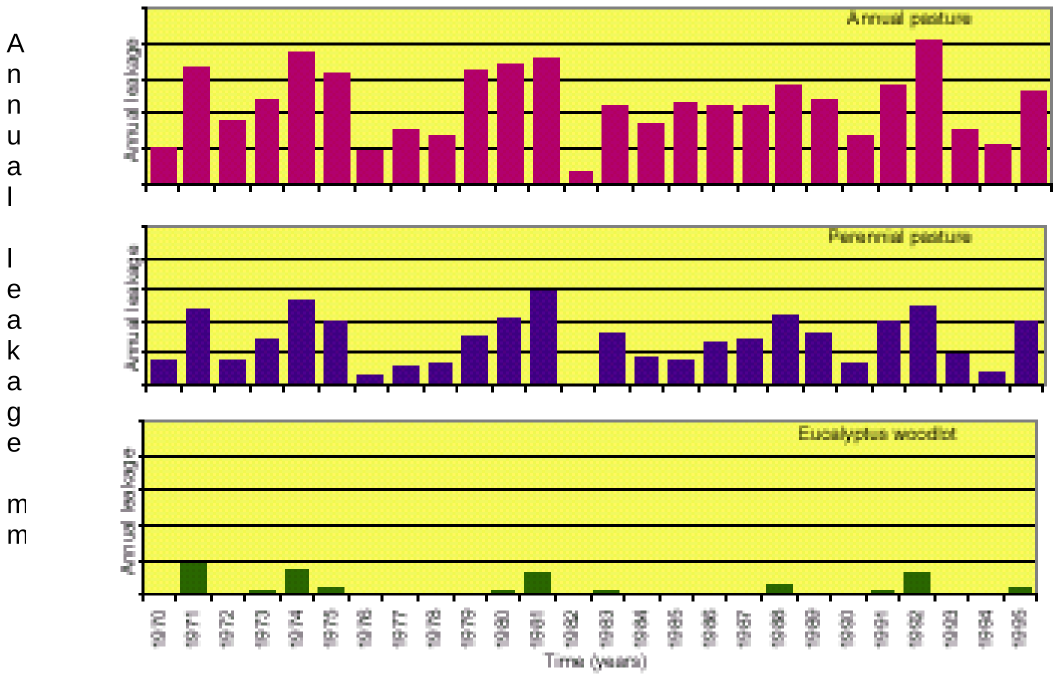
In 2000 the Tasmanian Salinity Audit was undertaken . This showed that there are many areas in Tasmania where there is existing salinity (about 3% of cleared agricultural land) with many more areas of Tasmania with the potential to become saline. Most of the saline and potentially saline land occurs in the below 750 mm average rainfall areas. However there is some in wetter areas like King Island.

New areas will become saline if land use changes cause an increased amount of water to pass below the root zone and this water passes through existing salt stores or causes salty water tables to rise and discharge to the surface.

Although an area may have been mapped as containing salinity it cannot be assumed that a land use change will cause an increase in salinity because salty stores or saline water tables may not exist in the area.

Land use changes which can increase the availability of water for deep percolation are land clearance, a change from perennial pastures to annual pastures or cropping rotations (see figure 15) and the use of irrigation, either for cropping or pastures.

Figure15. Water leakage under various vegetation types



This figure shows the results of simulation studies to assess the annual amounts of leakage for three vegetation types over 26 years at Hamilton in Victoria. While the amount of leakage varies considerably between years, leakage under perennials is generally less than it is under annuals, while leakage under trees is significantly less than under annuals or perennials. (G.Walker, M.Gilfedder & J.Williams, 1999; Effectiveness of Farming Systems in Control of Dryland Salinity, CSIRO Land and Water, 1999.)

With current irrigation methods and irrigation scheduling, the contribution of irrigation to deep percolation is not likely to be as great as the changes induced by converting land from perennial pastures to annual cropping rotations.

Based on mainland research it has been shown that it is the time in the year when crops are not growing, (eg, when soil is under cultivation or stubbles) that extra water accumulates and most of the extra water will percolate past the root zone.

The amount of extra leakage from rainfall has been estimated to be:

- up to 1% of rainfall for perennial deep rooted native vegetation
- from zero to 10% of rainfall for deep rooted perennial pastures
- between 30 –40 % for annual shallow rooted crops and pastures and
- up to an extra 10% of irrigation water applied if an efficient spray irrigation system is used.

The change to irrigation cropping often introduces dryland crops into the rotation, so the impact of intensification of landuse changes at least two components of the hydrology described above.

Where there are no salt stores or salty water tables below the root zone and good quality water is coming into the system (rainfall or irrigation water) there will be a very low risk that any increase in salinity will occur. For example farmers have been irrigating the red ferrosols of the NW coast for decades and because there is generally little salt stored in these soils no significant salinity has occurred. The exception may occur when these basaltic soils overly very shallowly other rock types which have accumulated salinity.

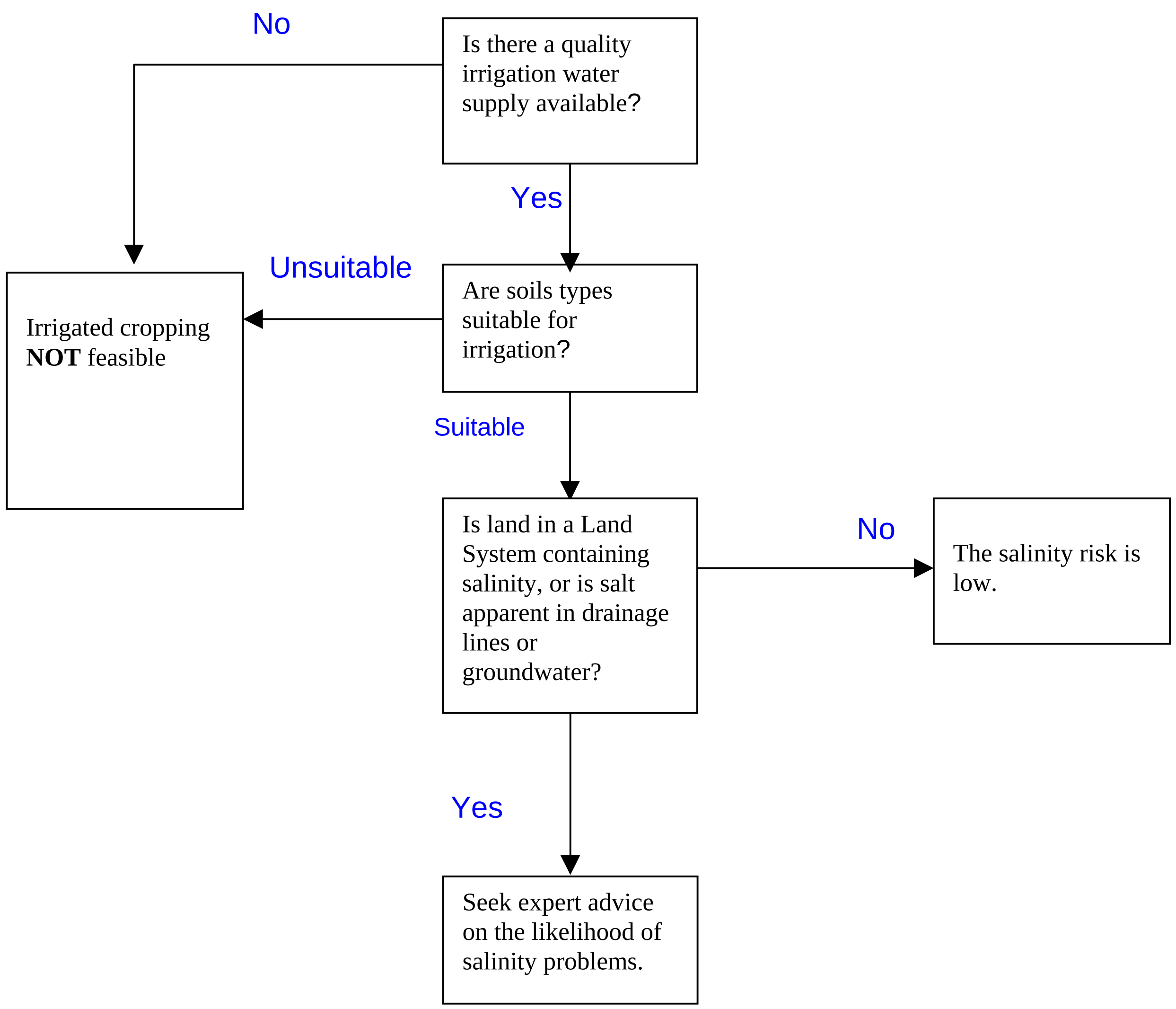
Where there is no salinity hazard, however, a change in land use from pasture to cropping and to irrigation will still cause extra water to be available and this may cause increased waterlogging or fresh water discharges.

Determining whether your land has a salinity hazard

To help farmers to assess the salinity hazard on their land a decision-tree process has been developed by the DPIWE (Colin Bastick).

It has been designed to provide a logical step by step process. At each step a key question is posed. The answer to this question will determine whether the landowner needs to investigate further.

Figure 16. Decision Tree for Salinity Risk Assessment



If there is a possibility of salinity developing, then monitoring of the depth and salt concentration of groundwater is the best technique to detect any impacts in the long term.

The keys steps are:

1. Water quality assessment.

   It is relatively common but not well recognised that groundwaters in Tasmania often contain elevated salinities.

   Also it is relatively common in drier areas of the state, for surface waters collected in catchment dams and from small steams to have elevated salinity. The salinity levels may vary from season to season and year to year.

   Application of saline water to land may cause damage to crops and soils.

> **How much salt are you adding to your soils**?
>
> Typically 2 mL of water is applied to a poppy crop and
> if this has a salinity of 1 dS/m (600 ppm), then
>
> *1.2 tonnes per hectare of salt is added per year*

   As a guide to the primary salinity risk the DPIWE has produced a fact sheet, Irrigation Water Quality *(Table 7*). More detailed information on the sensitivity of different plant species to salt is included in the notes for the Water Resources Module for this course.

   However, the effect of salinity on plants is not just a property of the salinity level but also of the chemistry of the salts that are in the water. If elevated salinity is found in water then a full chemical analysis is recommended. Interpretation of this analysis should be done by a person specialising in salinity and in conjunction with the appropriate information on the characteristics of the soils to be irrigated.

Table 7. Irrigation water quality

Irrigation water can be classified in terms of the measured conductivity level. These classes are outlined below.

Class	Ecw (dS/m)	Salinity Level
1	0 - .28	Low
2	.28 - 0.8	Medium
3	0.8 - 2.3	High
4	2.3 - 5.5	Very High
5	>5.5	Extremely High

- **Class 1:** Suitable for most crops on most soils, with little chance of developing a salinity problem.
- **Class 2:** May cause leaf scorch on sensitive crops, especially under high temperatures.
- **Class 3:** Should not be used on soils with restricted drainage. Under adequate drainage, management for salinity control will be needed.
- **Class 4:** very high salinity water is not suitable for irrigation under ordinary conditions. For this water to be used, soils must be permeable, drainage adequate, water must be applied in excess to provide considerable leaching, and salt tolerant crops should be selected.
- **Class 5:** Extremely high irrigation water may be used only on permeable, well drained soils under good management, especially in relation to leaching and for salt tolerant crops, or for occasional emergency use.

Detailed chemical analysis to determine the specific salinity components is recommended only for Class 3,4 and 5 waters, or for waters likely to be unnaturally contaminated.

Water conductivity (ie., salinity) is quickly and easily measured with a Hanna DiST Conductivity meter (available with SALTPAK; contact DPIWE).

2. Soils should be assessed for suitability for irrigation relative to:

    the cropping enterprise proposed (determined by soil physical and chemical assessment), and

    the quality of the water to be used.

This will involve an assessment of the soils on the farm, and possibly a soil survey, and may result in reorganising the farm layout so that the best soils are used for cropping and the poorer soils are excluded.

3. Salinity hazard assessment

   If it has been found that the water is suitable and there are sufficient soils for irrigating, the next step is to assess whether there is an inherent salinity hazard below rooting depth.

   That is, are there salt stores within the soils and substrate below the rooting depth, which could be mobilised? Are there shallow water tables in the proposed area?

   The shallowness of the watertable and the salinity of the ground water will determine the degree of hazard. Similarly, the level of salt stores in the soil profile will determine the degree of hazard and subsequently the degree of risk from land use change.

   The location of salt storage in the landscape and within soil types varies considerably and is not easily predicted using conventional soil surveying techniques.

   Similarly the locations of saline water-tables and the quality of water in those water-tables is not generally predictable from the surface.

   To solve these two problems economically, salinity hazard can be mapped using mobile electromagnetic induction techniques which look beneath the surface, and by ground-water studies using strategic drilling.

   The electromagnetic induction meter (EM31) is used produce a map of apparent soil conductivity and possible areas of salt storage and shallow ground water. Readings from the EM equipment are influenced by soil moisture, the amount of clay in the profile and salt content.

   The apparent soil conductivity map is used to locate a strategic drilling program. The drilling provides soil samples which are analysed for salinity (to establish the relationship between the readings produced by the EM31 and soil salinity). The drilling program also provides bore holes which are used to assess the depth to any water-tables, the quality of the ground water and some ground water flow information. These bores can be established for long-tem monitoring.

   The calibrated EM results and the analysis of watertables are combined to produce maps of the critical areas of high salinity hazard which should be avoided. They also provide the basic data on the areas where there is likely to be leaky soils which will allow deep drainage of water to migrate through salt store and down to ground waters.

Once completed an economical and robust monitoring program can also be implemented.

4. Assessment of changes in salinity levels under irrigation - establish on-going monitoring

   If it is decided to proceed with irrigation on a site where it has been established that there is a salinity hazard, it is recommended that a soil and water table monitoring program is set up. This will provide an early warning system to detect changes in salinity levels in the root zone and to detect any rising trends in ground waters below the area cropped.

   The maps of apparent soil conductivity soils and water-tables generated from the EM 31 survey can now be used to establishing the monitoring program.

   The maps will show where there are higher risk areas for soil degradation, salinity and ground-water changes. In these areas piezometer bore nests should be set up to monitor the movements in the watertables and trends in salt concentration.

   The DPIWE contact is Colin Bastick, Regional Land Management Officer (North).

Monitoring watertables

In most irrigation areas where impermeable layers of soil exist, such as clay layers, excess irrigation water will build up forming a watertable. The watertable can be found by digging a hole 2 to 3 metres deep. When you reach ground that is so wet that water flows into the hole, you have reached the watertable.

At the beginning of an irrigation season, these watertables are usually deep and do not affect your crop. However, as the irrigation season progresses and more irrigations are applied, if care is not taken these watertables may rise into the rootzone causing crop waterlogging and root rot which will in turn affect crop health and yield.

The depth of watertables beneath your crops needs to be monitored. This can be achieved through the use of testwells.

How do testwells work?

A testwell is a length of slotted PVC pipe installed vertically in the ground until reaching am impermeable layer (maximum depth say 2.5 metres). As the water table rises the water level in the testwells also rises. The depth of the watertable can be easily measured with a tape measure of graduated dowel, and will identify problems such as rising water tables.

The salinity of the groundwater can also be easily measured by obtaining a sample from the testwell.

Measuring testwells can be used to aid irrigation. If after an irrigation the watertable rises substantially (over 50 cm), then the irrigation was too heavy and a large amount of water was wasted.

If the watertable rises gradually from irrigation to irrigation, the amount of water being applied needs to be reduced or irrigations need to be spaced further apart.

If the watertable rises slightly after irrigation and then falls again before the next irrigation, the irrigation schedule is about right.

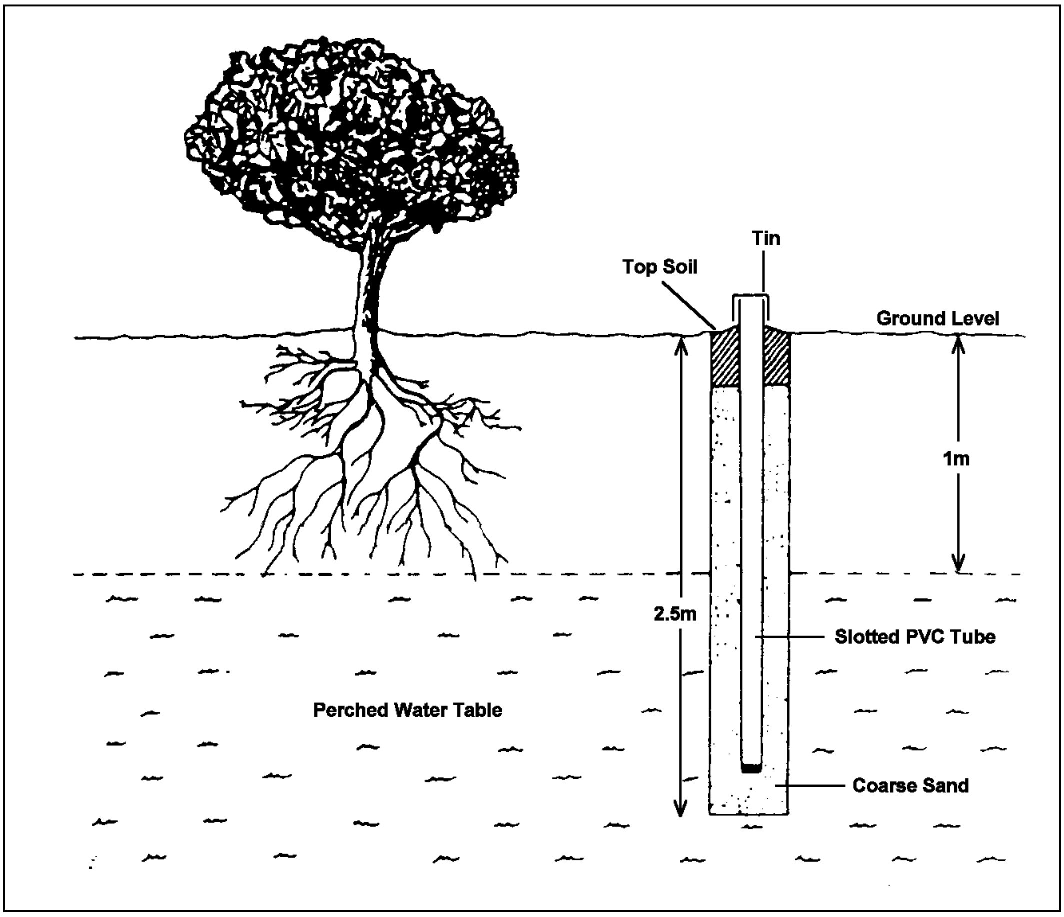
Where and when to install a testwell.

Install testwells on a grid across your property, ensuring that low lying and problem areas are included. They should be located at each tensiometer station as this helps to fine tune irrigation scheduling.

If tile drains are installed on the property, the testwell should be located midway between the drains. Choose a convenient site to install the testwell to avoid damage during normal property operations.

Installation should occur during winter, when the watertable is at its lowest level. Do not install soon after an irrigation.

Figure 17. Test well installation.



Reading and recording testwell measurements

Testwells should be read before an irrigation and one to two days after an irrigation. The readings should be entered in a record book, as well as rainfall and irrigation applications if these have not already been recorded.

It is important to identify the location of the testwell stations by recording a site number and the date and time when the readings were taken.

For easier interpretation of your results, testwell readings should be plotted on a testwell monitoring chart.

Indirect impacts of irrigation

The five main soil types described previously can be used as a predictor of the potential for soil structure decline associated with irrigated cropping because particular soil types, such as duplex soils, have been identified as being more susceptible to decline than soils with heavier topsoil textures (clay loams) which have greater resilience to structure decline.

Land management practices in association with land use can also be used to predict soil structure decline. For example, the greater the frequency of cultivation in a cropping rotation, the greater the potential for soil structure decline.

Research by the DPIWE (Bill Cotching) has found that when potatoes were included in the cropping rotation on duplex soils (sodosols), there was degradation of soil physical properties in the form of decreased aggregate size and aggregate stability, lower infiltration rate and increased bulk density. Farmers also reported more unhealthy soil attributes after potatoes, particularly after a wet potato harvest. These changes in soil structure are not associated with growing other crops such as cereals, poppies and peas.

On deep sandy soils (tenosols), subsoil compaction and increased bulk density were found to be associated with cropping, particularly after potatoes.

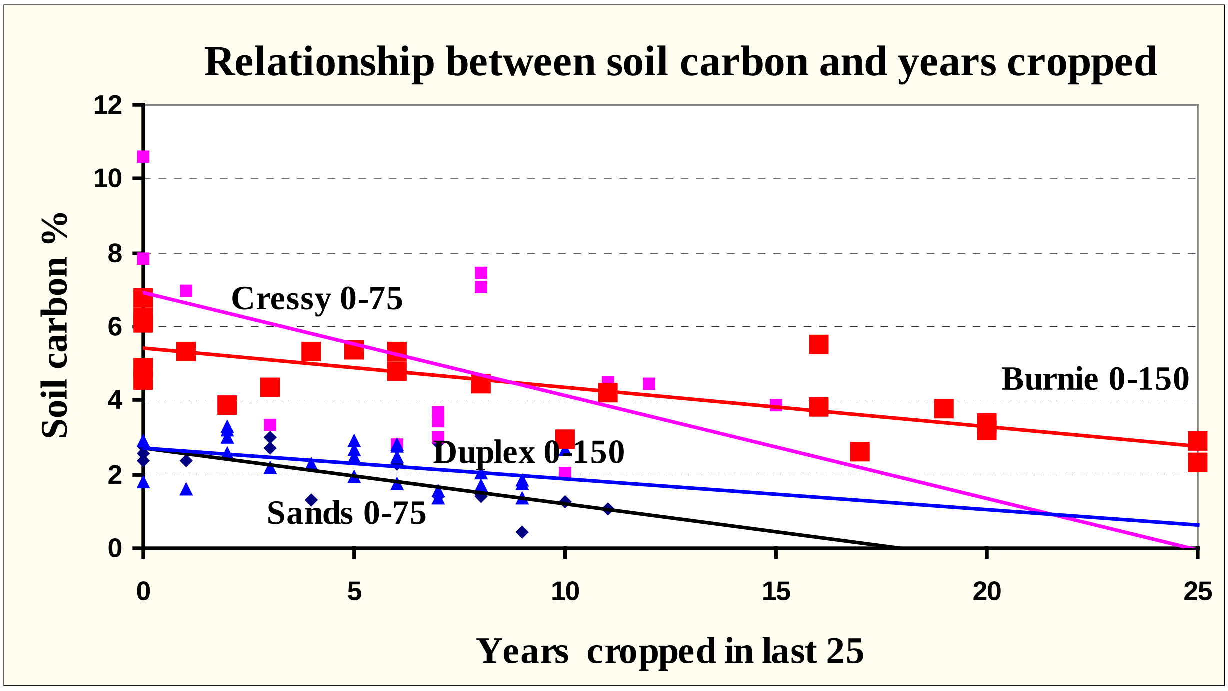
On Burnie and Cressy clay loams (red ferrosols and dermosols), changes in soil structure following cropping were visible to the naked eye as larger and blockier aggregates, which were harder to break up than those under pasture. Bulk density increased, but not enough to restrict root growth. Aggregates were less stable following cropping but these soils still remained in the highly stable class. Profiles of penetration resistance showed that there was no significant subsoil compaction associated with cropping.

Rain fed cropping on the black cracking clays did not result in soil structure decline but irrigated cropping resulted in increased topsoil bulk density and larger clod sizes.

Soil structure is generally damaged by cultivation and improved by root growth that occurs when the soil is undisturbed under a pasture phase.

DPIWE research has shown a very rapid decline in Organic Carbon in the topsoil associated with cultivation. Organic carbon is intimately associated with soil structure and its resistance to stress. Consequently, the magnitude of the changes in soil carbon and structure attributes associated with cropping is of concern, particularly for soils in Tasmania's Midlands which have been cropped for only a relatively short time.

Figure 17. Changes in soil carbon after cropping.



Interpretation

- Research shows that irrigated cropping on the five main soil types has resulted in structural degradation to varying degrees.
- Soil structure decline results in:

  greater surface runoff and potential for erosion;

  increased likelihood of surface crust formation and poor seedling emergence;

  reduced resistance to wind and water erosion;

  greater resistance to root growth and poorer plant performance, and

  lower organic matter levels reduce the ability of soils and plants to withstand stress imposed by diseases, climate and machinery effects.

Cropping rotations need to be selected with the knowledge that root crops result in significantly more degradation than other crops, and several years are required to rehabilitate soils once they are degraded.