1. Total Exchange Capacity (TEC) Ideal 10 to 18 ME

The exchange capacity of a soil is simply a quantitative measure of the soil's ability to hold exchangeable cations - the capacity of a soil to exchange nutrients. Clay colloids (extremely fine clay particles) and humus carry a negative charge that attracts and holds positively charged elements called cations - calcium, magnesium, potassium, sodium, hydrogen and some of the trace elements.

This nutrient holding capacity or colloidal energy of a soil is measured as milliequivalents (ME)/100gm of dry soil and is determined by the proportion of clay particles and the amount of humus present. This is recorded as the TEC or CEC.

The TEC will determine the fertiliser practices that are appropriate for a soil and the amount of nutrients needed to correct imbalances – ie. it will take more fertiliser to balance a high TEC clay than a low TEC sand. The sand will need smaller but more frequent applications of nutrients. In Australia typical soil TEC values range from 5 to 40 ME.

2. Bar Chart and Graph

The desired levels of nutrients depicted by the bar graphs are directly related to the soil's exchange capacity.

Eg. 17% base saturation of Mg will show as high in a soil with good TEC but low in a sandy soil with low TEC. The desired levels are specific to the soil tested.

The pie charts show the ideal balance of cations (Ca, Mg, K, Na, other bases and Hydrogen) and the levels found.

Deficiencies and excesses are reported in kg/Ha for easy calculation of fertiliser requirements.

3. pH (Water) Ideal 5.8 to 6.5
pH (Calcium Chloride) is available on request

Soil acidity or alkalinity refers to the concentration of hydrogen ions (H^+) in the soil solution, or more correctly, the relative concentration of H^+ and hydroxyl (OH^-) ions. The degree of acidity (alkalinity) of a soil is expressed by means of the pH scale. Solutions which contain equal concentrations of H^+ and OH^- ions are said to be neutral and have a pH of 7.0.

Solutions in which the concentration of H^+ ions exceeds that of OH^- ions are said to be acid and will have pH values less than 7.0. The greater the concentration of H^+ ions, the greater the acidity and the lower the pH value. Solutions in which the concentration of OH^- ions exceeds that of H^+ ions are said to be alkaline and have pH values greater than 7.0.

pH IS ONLY A MEASUREMENT OF HYDROGEN, NOT AN INDICATION OF SOIL FERTILITY OR MINERAL BALANCE

4. Organic Matter Ideal 4 to 6 %

The term "soil organic matter" refers to the whole range of organic materials present in the soil, including living organisms, dead and decaying plant and animal remains, and the amorphous dark coloured material known has humus.

The APAL test measures only the very fine or colloidal organic matter, and does not include bulk material like straw and roots. It is therefore a good indicator of soil humus levels.

Organic matter is the unifying element in the soil, having a prominent influence on soil organisms, plant growth and on the physical properties of the soil. Various components of organic matter perform the following functions:

- Attract and hold cations (positive charged elements) and trace elements in an available state, reducing leaching losses.
- Bind soil particles into aggregates, producing a granular structure which permits the accessibility of air to roots, the capillary movement of water, and the penetration of roots through the soil.
- Soak up and hold water.

4a Low Organic Matter

When organic matter is low, a lower level of natural nitrogen is available to plants and water holding capacity is reduced. Other problems are lowered microbial activity and reduced mineral availability, especially of boron. There will be a higher requirement for artificial nitrogen in these soils.

4b High Organic Matter

High organic matter on a test can indicate a soil that has a poor level of microbial activity. It can also indicate that there is a large amount of dead and trampled grass on the soil surface forming a thatched layer, thus reducing turf or pasture growth, and inhibiting plant root development. When soil samples have a layer of dead plant material on top of the cores, this is usually an indication of limited microbial activity, often as result of low calcium levels.

5. Nitrogen Ideal 90 to 120 kgs/ha

This is a calculation of the amount of nitrogen available from the organic matter present. If the organic matter is low (eg 2-3%) then there may not be enough natural nitrogen in the soil for adequate turf growth and extra should be applied.

Plants have a higher requirement for nitrogen than for any other nutrient but the amount that needs to be applied in fertilisers will depend on amount of growth wanted and the supply from natural soil sources like organic matter breakdown and atmospheric fixation by legumes.

If plants have a good supply of all other nutrients, then growth can controlled with nitrogen applications. Only supply enough nitrogen to produce the cover and appearance needed for a particular application, because excess growth will waste time and resources.

Too much nitrogen will produce excess lush (soft) growth, which is susceptible to disease and insect attack – shoot growth at the expense of root growth.

Too little nitrogen will result in limited pale shoot growth and the turf or pasture will tend to thin out and be prone to weed invasion.

Turf - Nitrogen is best applied in small amounts frequently rather than in heavy applications. Don't use more than 0.5 kg N / 100square metres at a time.

6. Sulphate   Ideal 20 to 30 ppm

Sulphur (S) is an essential plant nutrient and is required by plants in amounts similar to phosphorus. The most important function of S in plants is it's involvement in protein synthesis. Sulphur is present in the structure of the amino acids cysteine and methionine, both of which are important components of proteins. As much as 90% of the total sulphur in plants may be present as protein-S.

7. Phosphorus - Bray 2 Analysis   Ideal Levels

This is the standard APAL phosphorus test, however an **Olsen phosphorus test** is now conducted on all samples in addition to the Bray test

(Ideal levels are expressed as kg/ha of P).

	Phosphorus (P)
Sheep/Cattle Pasture	65 -115 kg/Ha
Dairy/Irrigated Pasture	135-180 kg/Ha
Cereals/Oilseeds/Pulses	115-180 kg/Ha
Vines/Olives	160-230 kg/Ha
Horticulture/Vegetables	275-330 kg/Ha
Turf	115-160 kg/Ha
Gardens/ Orchards	230-275 kg/Ha

Phosphorus is expressed as kg/ha. This makes it easier to calculate the amount of fertiliser needed to meet an identified deficiency.

Eg. if the deficiency is 50 kg/ha P then you will require:

250 kg DAP (20% P = 20 kg P/100 kg DAP)
500 kg Rock Phosphate (10% P = 10 kg P/100kg RP)
556 kg Superphosphate (9% P = 9 kg P/100kg Super)

Although your actual application rate will depend on budget restraints, the soil test will give you a good basis for fertiliser planning.

Phosphorus is important for cell division and growth. It is needed for photosynthesis, sugar and starch formation, in energy transfer and movement of carbohydrates around the plant, and is concentrated in the growing tips.

Deficiency is seen as a stunting of growth with deep green or purpling of leaves a common visible symptom.

A deficiency of phosphorus will greatly reduce the growth of plant tops and roots – it is essential for early root development and plants need a readily available source of P in the early growth stages or crop yields will be reduced.

7a Olsen P

APAL now conducts an Olsen phosphorus test on all soil samples in addition to the Bray test. Olsen analysis can be more accurate at high pH levels than Bray 2. Some general target levels are:

	Phosphorus (ppm)
❑ Sheep/Cattle Pasture	20 – 25ppm
❑ Dairy/Irrigated Pasture	30 – 40ppm
❑ Cereals	20 – 30ppm
❑ Oilseeds/Pulses	25 – 30ppm
❑ Vines/Olives	35 – 35ppm
❑ Horticulture/Vegetables	45 – 55ppm
❑ Turf	30 – 40ppm
❑ Gardens/ Orchards	35 – 40ppm

Conversion of Olsen P to Colwell P

In some soils the relationship between Olsen P and Colwell P has been found to be reasonably constant. This is the case in the Mid-North of South Australia where the SA Dept of Agriculture developed the conversion factors below:

SAND	Olsen mg/kg **x 1.25** = Colwell mg/kg
LOAMY SAND	Olsen mg/kg **x 1.75** = Colwell mg/kg
SANDY LOAM	Olsen mg/kg **x 2.00** = Colwell mg/kg
LOAM	Olsen mg/kg **x 2.50** = Colwell mg/kg
CLAY LOAM	Olsen mg/kg **x 3.00** = Colwell mg/kg
CLAY	Olsen mg/kg **x 3.50** = Colwell mg/kg

This relationship will vary between regions and soil types so use it as a guide only

7b P-Recovery Can vary from 0% to 100

P-Recovery is a laboratory calculation of the amount of P that is available to plants after interaction with the soil following fertiliser application. For example a P-Recovery of 50% means that if 10 kg of Phosphorus is applied to the soil as fertiliser, only 5 kg would be available to the plants. P-Recovery can be used to determine the desired level of P for a particular soil - a high P-Recovery means a lower reading of P is acceptable, but if P Recovery is low (< 40%), then a higher level of available P is required.

8. Calcium

Ideal Ca:Mg Ratio 5.5:1 in high TEC soils
3:1 in low TEC soils

Ideal percentage of base saturation is 60 to 70% for pastures, tree crops, legumes and cereals, 60% for berry fruit, grapes and low fertility grasses, 48% for blueberries, pine trees and acid loving plants. Calcium can be supplied as agricultural lime, dolomitic lime or gypsum. Dolomite is used where there is also a magnesium requirement or where a lime application will create a soil magnesium deficiency.

Calcium is essential for the proper growth and function of root tips. It is also found in large quantities in leaves where it is a constituent of the cell wall. Calcium is thought to encourage earthworm activity and thus can increase the natural aeration of the soil. A good level of calcium is also associated with stable soil structure. This is due partly to the increased activity of soil organisms and partly to an increase in flocculation of the clay particles. Both excess and a deficiency of calcium will create a phosphate deficiency.

8a Calcium/pH

Your Calcium recommendation is based on soil deficiency, not on pH. This recommendation will be for Calcium Carbonate (Lime), Dolomite or Gypsum, depending on the percentages of Calcium and Magnesium reported in the analysis.

Note that applied Calcium will displace soil Magnesium, so Dolomite will often be recommended if soil Magnesium is below 14% Base Saturation. If in doubt, discuss this with your consultant.

Calcium will also suppress the uptake of manganese, so a deficiency may be induced by the application of lime or dolomite, especially if soil Manganese is low. Reports will indicate if a foliar spray of Manganese is required.

9. Magnesium

Ideal base saturation percentages of 10 - 20% depend on the TEC, so that the actual amount of magnesium available is maintained in balance. 10% is required in high TEC soils and 20% in very low TEC sands.

Magnesium is essential for both animal and plant production. Magnesium is also one of the cations (along with Ca, K, Na & H) that construct the soil pH. This means that any one of these cations can be the main contributor to the level of pH, therefore it is very important to know just how the pH is constructed. Excess soil magnesium can give a good pH even when soil calcium is low, but this imbalance is not desirable.

9a Excess Magnesium

Excess Magnesium will often give a good pH on low calcium soils. When this happens soils are compacted, pastures unpalatable and stock performance lower than expected. Excess Mg can suppress plant potassium and boron and these soils are nitrogen deficient with extra artificial nitrogen required for optimum crop or pasture growth. In livestock, animal magnesium levels are often low on high magnesium soils. This can be due to higher levels of plant nitrates as a result of excess soil magnesium. The calcium/magnesium balance is very important, but it must relate to the desired percentages of Ca and Mg.

10. Lime, Gypsum or Dolomite?
Selection for particular soils.

The selection of one or a combination of the above materials for a particular soil should be based on the levels of Calcium and Magnesium found, not on the pH.

All are naturally mined materials and the quality will vary, so always check your local sources before purchase. A good quality product may contain:

LIME (Calcium Carbonate)……………………………	35% Calcium	
DOLOMITE (Calcium/Magnesium Carbonate)….....	20% Calcium	10% Magnesium
GYPSUM (Calcium Sulphate)……………………….	20% Calcium	16% Sulphur

(A) Soils low in both Calcium and Magnesium
are often lighter sandy soils and require Dolomite.

(B) Soils low in Calcium with high Magnesium
require Lime or Gypsum or a combination of both.

When Ca is very low, Lime is the first amendment used. Gypsum is used after exchangeable Ca reaches 60%. This is because the sulphur in Gypsum can leach Ca when Ca% is low, making it difficult to lift levels.

(C) Soils low in Calcium with good Magnesium
require Lime or Dolomite.

Addition of Lime to soils will increase calcium while at the same time displacing some magnesium.

Where significant applications of calcium are made, it is possible for good or even slightly high magnesium to be pushed down below desirable levels.

Therefore, Dolomite can be recommended on soils with good or above ideal Mg to maintain adequate levels, while Ca increases.

11. Potassium Ideal 2 to 5% Base Saturation

The desired level depends on the exchange capacity (TEC) of the soil. Light soils <6 TEC require a higher percentage of K - 6%. Heavier soils >20 require 3% K. This is due to the fact that there more exchange surfaces in a high TEC soil so there is also a higher amount of potassium available.

Plants require relatively large amounts of potassium. Potassium also affects the pH construction, so soil excess will increase pH, as will K fertiliser application.

12. Sodium Ideal 0.5 to 3% of Base Saturation

Essential for stock and certain plants and to a lesser degree for soil balance. Sodium is also part of the pH construction so excess will increase pH. Saline soils have a high pH.

13. Micro Nutrients

With the exception of molybdenum and selenium, the plant availability of all micro nutrients decreases with an increase in soil pH. Availability is highest in acid soils and lowest in soils with pH values of 7.0 or above. Conversely molybdenum and selenium are most available in soils of high pH and least available in acid soils.

14. Cobalt Ideal 1.5 to 2.0 ppm

Cobalt is essential in ruminants for the formation of vitamin B12, and deficiencies result in anaemia, loss of appetite, infertility and poor growth rates. Severe deficiencies will result in death, however in marginal cases reduced growth may be the only sign of deficiency. In marginal areas cobalt is more likely to be deficient during wet periods and periods of rapid, fresh growth because the cobalt taken up is distributed through a larger plant mass and the animals are unable to ingest enough for their requirements. Vitamin B12 injections can be used regularly if a deficiency is suspected. For longer term results use cobalt bullets, although these may not be totally effective or appropriate for some animals. Cobalt can also be added to fertiliser or to the water supply. Blood test regularly to monitor levels.

15. Boron

The desired level is 0.8ppm for grasses and cereals, >1.5ppm for fruit trees and >2.0 ppm for legumes.

Boron is essential for photosynthesis and energy production in plants. It also acts as a modifier in helping to maintain the balance between calcium, potassium and magnesium, especially when one of these major cations is in excess and creating a major imbalance. It is needed for the development and growth of new cells, and since it is not readily translocated within the plant, the first visual sign of boron deficiency is often the cessation of growth of buds or shoots. This is followed by the death of young leaves, so boron deficiency often gives plants a bushy appearance. In fruit trees, large amounts of bare wood is another symptom - fruit will often grow in bunches with bare wood between these bunches, especially on the higher branches because fruit and leaf buds have aborted in the spring.

Wheat heads can also give a bushy appearance and show white tips. Boron increases Calcium absorption in plants and animals, increases fruit quality and shelf life and also increases the oil percentage in canola.

Boron is also involved in many other essential plant processes, including the translocation of sugars and other bio-chemicals, protein synthesis, nodule formation in legumes and the regulation of carbohydrate metabolism (energy). In pastures, boron helps to balance nitrogen levels and prevents the excess accumulation of nitrate nitrogen, thus reducing excess protein in spring and autumn pasture - this is also the case in fruit crops. Boron may also reduce incidence of bloat in cattle.

15a Boron Toxicity

Boron toxicity can be a problem where drainage is poor or where there is an impervious subsoil layer where Boron accumulates.

Determine subsoil conditions before applying Boron with fertiliser.

Boron can also become toxic in low Calcium soils so the application of calcium will help to reduce boron toxicity.

16. Iron — Ideal 100 to 400 ppm

Iron has many important functions in both plants and animals, including its presence in haemoglobin and its involvement in the synthesis of chlorophyll. Deficiencies can be caused by over liming. Excess in feed will suppress copper and zinc uptake in livestock.

17. Manganese — Ideal 80 to 140 ppm

Manganese is essential for many important plant functions, including photosynthesis, nitrogen metabolism and nitrogen assimilation. Manganese is essential for calcium uptake by plants. Deficiency symptoms are common in cereals growing on highly alkaline soils and generally appear as a yellowing of the leaves and roots that are covered by a thick film which is easily wiped off leaving a thin white strand for the root. Manganese deficiency in stock shows as bent front legs in the new born lamb or calf.

Plant level can also be suppressed in high Potassium soils or following calcium or potassium applications.

18. Copper Ideal >2.0 ppm

Livestock: copper is an essential nutrient for animals and is often deficient when they graze pastures low in copper. Copper deficiency can be induced by excess soil molybdenum and iron. Sheep have a lower requirement than cattle and deer. Eg animal copper requirement is related to the animals bone size.

The copper available to plants is affected by the soil pH - as the pH increases so copper availability decreases.

Plants: copper is involved in many plant processes. It is essential for photosynthesis and for protein and carbohydrate metabolism. Copper also appears to be required for nitrogen fixation by rhizobia bacteria. In severe deficiencies leaf tips turn almost white and leaves become narrow. In cereal grains the seeds fail to develop leaving blind ears. A deficiency often shows as lodging.

19. Zinc Ideal 8 to 10 ppm

Zinc is a nutrient for both animals and plants. In plants it promotes growth hormones and starch formation and it is involved in seed maturation and production. Grain seed heads often fail to completely fill if zinc is deficient. It is essential for moisture absorption into roots.

20. Molybdenum 0.4 to 0.6 ppm for Stock
0.8 to 1.5 ppm for Plants

Essential for both plants and animals. In plants it is needed for nitrogen fixation by clovers and lucerne. Essential for nitrogen utilisation, especially in brasiccas.

Low soil levels will also reduce total production - production of many vegetables is reduced by molybdenum deficiency. Deficiencies occurs mostly at a pH <5.

In livestock excess levels in pasture can adversely effect stock health by reducing the absorption of copper and so induce copper deficiency. This problem has been caused by the excessive use of molybdenum in fertilisers.

21. Aluminium Ideal - less than 2.0 ppm

High soil Al levels can be toxic to plants although there is a wide variation in tolerance between species. Lucerne, barley, medics and canola are highly sensitive while oats, triticale and lupins are very tolerant.

Aluminium is only a problem in low calcium soils so addressing the Lime or Dolomite requirements is the priority and will overcome any toxicity problems.

Soil Aluminium levels are not a reliable indicator of lime requirement and it is much better to apply lime based on exchangeable calcium present.

22. Conductivity $EC_{(1:5)}$ Ideal - less than 0.15 dS/m

The conductivity of a 1:5 soil water solution is measured to determine the level of salts present. Conductivity can be elevated by the application of fertiliser and gypsum as well as by the presence of sodium chloride (salt). It is important to leach the soil after applying gypsum or broadcast before winter rains.

APAL can also conduct an Saturated Paste Extract (**EC_e**)conductivity test as an option. This gives a genuine **EC_e** result and is not simply a calculation from $EC_{(1:5)}$. This test is used by soil surveyors and is regarded as a more accurate measure of soil salinity than $EC_{(1:5)}$.

23. Chlorides Ideal - less than 200ppm

APAL now uses ASPAC method 5A1 to measure soil chlorides. The original method used resulted in higher numbers than the ASPAC procedure so the desired levels and graph reports have been adjusted accordingly.

The desired maximum chloride levels will vary with soil texture:

Sand to sandy loams	< 120ppm
Loams to clay loams	< 180ppm
Clays	<300ppm

Plant damage can occur above these levels depending on plant tolerance and how well drained the soil is.