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Soil Quality in the Marlborough Region 2015

RE500/2016/004

January 2016

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Report prepared for Marlborough District Council

January 2016

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1. Executive summary

The Marlborough District Council (MDC) has a duty under the Resource Management Act (1991) to monitor the “life supporting capacity of soil” and determine whether current practices will meet the “foreseeable needs of future generations”. To help meet these goals the MDC undertakes a soil quality monitoring program that involves collecting soil samples from sites that represent the main land use activities and soil types in the Marlborough region and analysing samples for a suite of soil physical, biological and chemical properties that have been shown to be robust indicators of soil quality.

In this investigation, soils were re-sampled from 13 soil quality monitoring sites first sampled in 2010. The sites included four different land use activities including cropping, viticulture, dairy and drystock pasture across 11 different soil types from three soil orders.

The monitoring has highlighted that there are some soil quality issues under some land use activities. The main issue was some evidence of poor soil physical condition under some landuses. For example, all the cropping sites showed evidence of either soil compaction i.e. high bulk density, and/or low aggregate stability. These sites also often had low or depleted soil carbon contents. This puts these soils at risk of poor aeration, impeded drainage and surface crusting, all which may potentially affect crop performance and predispose the soil to surface runoff, nutrient loss, erosion and flooding. One of the dairy sites and the wheel track areas of several vineyard sites also showed evidence of poor physical condition i.e. low macroporosity due to heavy grazing or grazing under wet conditions and machine activity, respectively.

The other issue was an elevated Olsen (Phosphorus) P status found at two of the cropping sites and one of the vineyard sites. High soil P has the potential to negatively affect water quality if it ends up in surface water bodies. Implementation of nutrient budget plans will help minimise excessive nutrient accumulation in soils, while farm management plans can help identify source areas for P accumulation and present site specific mitigation methods that could implemented on farm.

It is recommended that to obtain reliable, long-term detection and prediction of trends in soil quality, at least three and preferably five points along a time sequence should be obtained. Therefore repeat monitoring of sites should be conducted in the medium-term (≈ 3 - 5 years) to determine trends over time.

2. Introduction

Regional councils (and Unitary Councils) have a responsibility for promoting the sustainable management of the natural and physical resources of their region. One of the physical resources that they have a duty under Section 35 of the Resource Management Act (1991) to monitor and report on is soil, specifically to report on the "life supporting capacity of soil" and to determine whether current practices will meet the "foreseeable needs of future generations". The collection of detailed soil monitoring data is therefore vital because it provides information on what effect current landuse activities are having on soil quality and whether they need to change or prioritise the way the land environment is managed. This is becoming increasingly important as some landuse activities are intensifying across some parts of New Zealand (e.g. dairying) putting pressure on our soils. Furthermore the way soils respond to different landuse activities can affect other parts of the environment. A good example is water quality, because soils act as buffers to capture and store nutrients such as nitrogen, phosphorus and microbes.

To help determine what effect landuse practices are having on soil quality, in 2000 the Marlborough District Council (MDC) became a participant in a national soil quality monitoring programme known as "The 500 Soils Project". At the completion of this project the MDC implemented its own soil quality monitoring programme commencing in 2008 to continue assessing the quality of soils throughout the Marlborough region. This programme is largely based around the framework developed as part of the national programme and is in line with soil quality monitoring currently undertaken in other regions in New Zealand.

The objectives of the soil quality monitoring programme are to:

- Provide information on the physical, chemical and biological properties of soils in order to assess overall soil health;
- Provide an early-warning system to identify the effects of primary landuses on long-term soil productivity and the environment;
- Track specific, identified issues relating to the effects of landuse on long term soil productivity;
- Assist in the detection of spatial and temporal changes in soil quality; and
- Provide a mechanism to determine the effectiveness of regional policies and plans.

The aim of this study is to report on the results of the second round of soil sampling on 13 sites that were originally established and sampled in 2010 and analysed for a suite of soil physical, biological and chemical properties – indicators of soil quality. Note this is two sites fewer than originally sampled in 2010 due to access for resampling being denied by the landowner in 2015. All soil sampling was undertaken by staff at the Marlborough District Council.

3. Materials and methods

3.1 Sample site

Soils were sampled from the same sites that were established, sampled and reported in 2010 (Gray 2010). A summary of the soil type, soil classification and landuse of the soil quality monitoring sites sampled are given in Table 1.

Table 1. Soil type, soil classification and landuse of soil quality monitoring sites.

Site code	Year established	Soil Order*	Soil series	Landuse	Sample location
MDC61	2010	Pallic	Seaview	Cropping	
MDC62	2010	Recent	Galtymore	Cropping	
MDC63	2010	Pallic	Marama	Cropping	
MDC64	2010	Pallic	Broadbridge	Cropping	
MDC65a	2010	Pallic	Seaview	Vineyard	Under the vine
MDC65b	2010				Under the wheel track
MDC65c	2010				Middle of the inter-row
MDC66a	2010	Brown	Kaituna	Vineyard	Under the vine
MDC66b	2010				Under the wheel track
MDC66c	2010				Middle of the inter-row
MDC69a	2010	Pallic	Woodbourne	Vineyard	Under the vine
MDC69b	2010				Under the wheel track
MDC69c	2010				Middle of the inter-row
MDC70a	2010	Recent	Wairau	Vineyard	Under the vine
MDC70b	2010				Under the wheel track
MDC70c	2010				Middle of the inter-row
MDC71	2010	Brown	Renwick	Cropping	
MDC72	2010	Pallic	Brancott	Cropping	
MDC73	2010	Brown	Kaituna	Drystock	
MDC74	2010	Recent	Rai	Dairy	
MDC75	2010	Recent	Ronga	Dairy	

*New Zealand Soil Classification

3.2 Soil sampling

Two types of soil samples were collected from each site. Firstly a composite sample comprising 25 individual cores taken at 2 m intervals along a 50 m transect to a depth of 100 mm. These samples were used for chemical and biological soil analysis. In addition, three undisturbed soil cores (100 mm diameter by 75 mm depth) were sampled at 15-, 30- and 45-m positions along the transect . The soil cores were removed as one unit by excavation around the liner, bagged and loaded into padded crates for transport to the laboratory for analysis. These soil samples were used for soil physical analysis.

At the cropping site, three additional samples were collected to assess aggregate stability. The samples were collected at the same interval as the intact cores by cutting a vertical block of soil with a spade approximately 10 cm square (10 cm high x 10 cm wide).

3.3 Soil quality indicators

A number of different soil properties were measured to assess soil quality. Soil chemical characteristics assessed were soil pH, total carbon (C), total nitrogen (N), C:N ratio, Olsen Phosphorus (P) and trace element concentrations. Soil biological activity was determined by measuring anaerobically mineralisable nitrogen (AMN). Soil physical conditions were assessed using bulk density, particle density and water release characteristics which in turn were used to calculate total soil porosity, air capacity and macroporosity, and at some sites aggregate stability (Table 2).

Table 2. Indicators used for soil quality assessments.

Indicators	**Soil Quality Information**
Chemical properties	
Total carbon content	Organic matter status
Total nitrogen content	Organic N reserves
Carbon:nitrogen ratio	Organic matter quality
Soil pH	Acidity or alkalinity
Olsen Phosphorus	Plant available phosphorus
Trace elements	Deficiency or toxicity of trace elements in soil
Biological properties	
Anaerobically mineralisable N	Microbial health. Readily mineralisable nitrogen reserves
Physical properties	
Dry bulk density	Compaction, volumetric conversions
Total porosity, air capacity and macroporosity	Soil compaction, aeration, drainage
Aggregate Stability	Indication of ability of soil aggregates to resist slaking, compaction and capping

3.4 Soil analysis

3.4.1 Chemical

All chemical analysis was undertaken by Hills Laboratory, Hamilton. Total C and N were determined by dry combustion of air-dry soil. Soil pH was measured in water using glass electrodes and a 2:1 water to soil ratio (Blackmore et al., 1987). Olsen P was determined by extracting soils for 30 min with 0.5 M $NaHCO_3$ at pH 8.5 (Olsen, 1954) and measuring the phosphate concentration by the molybdenum blue method. Trace element concentrations in soils i.e. total recoverable copper (Cu), chromium (Cr), cadmium (Cd), arsenic (As), lead (Pb), mercury (Hg), nickel (Ni) and zinc (Zn) were determined by digesting soils in nitric/hydrochloric acid and analysing trace elements in the digest by inductively coupled plasma mass spectrometry (US EPA 200.2).

3.4.2 Biological

Anaerobically mineralisable nitrogen (AMN) was estimated by the anaerobic incubation method. The increase in NH_4-nitrogen concentration was measured after incubation for 7 days at 40 ºC and extraction in 2 M KCl (Keeney and Bremner, 1966).

3.4.3 Physical

Soil physical analysis was undertaken by Landcare Research in Hamilton. Dry bulk density was measured on soil samples extruded from cores and dried in an oven at 105°C until the weight remained constant and the sample was then weighed (Gradwell and Birrell, 1979). Macroporosity (-10 kPa) and total porosity were calculated as described by Klute (1986). Particle density was measured by the pipette method. Aggregate stability was measured by wet sieving of the 2 - 4 mm soil fraction. The mean weight diameter (MWD) of aggregates remaining on the 2 mm, 1 mm and 0.5 mm sieve was measured after sieving (Kemper et al., 1986).

It is worth noting that the general definition of macroporosity has been expanded to cover a slightly larger range of pore sizes than the original definition. Several regional councils have adopted macroporosity measurements based on the volumetric water content at -10kPa (technically referred to as the air filled porosity). For consistency with other regions, this report uses the -10kPa measurement (defined in this report as macroporosity), although the -5kPa data is included for reference because this has been used and reported by the MDC and others in the past.

3.5 Targets and ranges

To aid in the interpretation of soil quality indicators, an expert panel (in several workshops) developed guidelines for the seven soil quality indicators now commonly used by regional councils (Hill and Sparling 2009). The panel determined target ranges for the assessment of soil quality (e.g. very low, optimal, very high etc) for the predominant soil orders under different land uses. The interpretative ranges from Hill and Sparling (2009) are presented in Appendix A. However, Olsen P targets have recently been revised from those reported in Hill and Sparling (2009) with new target values reported in Taylor (2011) and used in this report (Appendix A).

The trace element results (with the exception of Cd) have been compared against the soil limits presented in the New Zealand Water and Wastes Association (NZWWA, 2003) 'Guidelines for the Safe Application of Biosolids to Land in New Zealand' (referred to as the biosolids guidelines) (Appendix A). While guidelines containing soil contaminant values like the biosolids guidelines have been written for a specific activity (i.e. biosolids application), the values are generally transferable to other activities that share similar hazardous substances. Cadmium results were compared to values in the Tiered Fertiliser Management System (TFMS) from the New Zealand Cadmium Management Strategy (MPI, 2011).

3.6 Statistical analysis and presentation

Total C, total N, AMN and Olsen P are expressed on a gravimetric basis to allow comparison with their respective target ranges. To determine comparisons in soil quality indicators between soils sampled in 2010 and 2015, data were tested for normality and a paired t-test performed. All statistical analysis was undertaken using Minitab.

4. Results and discussion

4.1 Comparison of target ranges

Figure 1 shows the percentage of sites not meeting their target for a specific soil quality indicator. It should be noted that because the vineyard landuse was sampled in three locations (i.e. vine, wheel track and inter-row) at each site, it was decided that if any of the soil quality indicators in any of the three sample locations did not meet their respective target, the site was noted as non-compliant for that indicator.

Results show that soil pH, total N and AMN were within target ranges at all sites sampled, while total C at three sites (23%), bulk density at six (46%) and macroporosity at five sites (38%) were out of the target range. Olsen P was outside the target range at eight sites (62%), although as will be discussed in section 4.7, only three sites exceeded the upper limit of the target for Olsen P, with the remainder of sites below the target range.

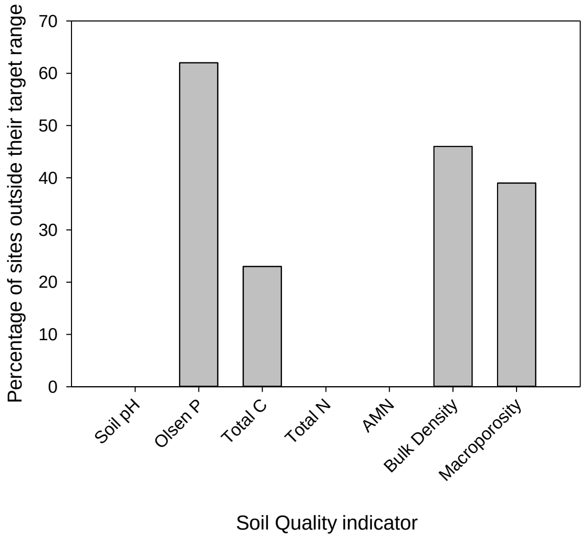

Figure 1. The percentage of sites not meeting their target range for a specific soil quality indicator.

The results of soil chemical, biological and physical analyses from soils sampled at each site are given in Table 3 and Appendix A, and are discussed separately below.

4.2 Soil pH

Soil pH is a measure of the acidity and alkalinity in soil. It is an important soil indicator because it affects nutrient and contaminant availability to plants and the functioning of beneficial soil macro- and micro-organisms. Most plants and soil organisms will have an optimum pH range for growth, and the pH of the soil affects which species will grow best.

Table 3 indicates all sites had soil pH values within the acceptable target for their respective landuse. Although all sites had soil pH values within their target ranges, two of the pasture sites (MDC73, MDC74) were outside what is deemed optimal range for pasture soils with a pH between 5.8 – 6.2, considered to optimise pasture production

(Roberts and Morton, 2009). These sites would benefit from an application of a liming product to increase soil pH where it has been assessed as economically viable.

4.3 Total carbon

Total C is the total amount of C in soil which includes carbonates and soil organic matter C. Typically New Zealand soils contain only small amounts of carbonate; hence total C is generally considered a good measure of organic matter C in soil. Organic matter is important for soil health because it aids in the retention of moisture and nutrients, contributes to a stable soil structure, provides a source of energy for soil microbes and is a source of nutrients e.g. N, P and sulphur (S). In contrast, low soil C (organic matter) increases the risk of structural degradation in soils e.g. low aggregate stability, high bulk density, low macroporosity, formation of surface crusts.

Table 3 indicates that all sites had total soil C contents within their acceptable target ranges for their respective landuse, with the exception of three of the cropping sites (MDC61, MDC62, MDC63) which were below the desired range. Two of the other cropping sites (MDC64 and MDC71) had soil C concentrations at the lower end of the desired range.

It would be desirable if cultural practices are adopted to increase the amount of soil C in this soil, either by increasing C inputs or decreasing the rate of decomposition of C. This could include adopting residue management practices that maximise C returns to the soil, grow cover crops over winter, include a pasture phase in rotations or adopt minimal tillage (Ghani et al., 2009).

Table 3. Soil chemical, biological and physical characteristics of soils sampled in 2015. Data highlighted in bold represent values outside the recommended target range. Red values are below the target range while blue values exceed the recommended target range. n.d. not determined.

Site code	Landuse	Soil type	pH	Olsen P	AMN	Total C	Total N	Bulk density	Macroporosity (-10k Pa)	Aggregate Stability	Macroporosity (-5k Pa)	C:N ratio
				(mg L^{-1})	(mg kg^{-1})	(%)	(%)	(Mg m^{-3})	(% v/v)	(mwd)	(% v/v)	
MDC61	Cropping	Pallic	6	**42**	44	**1.9**	0.21	**1.5**	10.1	1.59	7.9	9
MDC62	Cropping	Recent	6	24	33	**1.4**	0.15	**1.4**	13.2	**0.87**	8.8	9
MDC63	Cropping	Pallic	6.2	35	39	**1.9**	0.22	**1.5**	8.7	**0.99**	5.0	9
MDC64	Cropping	Pallic	5.8	**38**	49	2.6	0.26	**1.5**	**5.9**	**1.37**	4.2	10
MDC65a	Vineyard	Pallic	6	22	75	3.5	0.30	1.3	11.6	n.d.	9.3	12
MDC65b		Pallic	6.1	**19**	88	3.6	0.35	1.1	14.3	n.d.	11.5	10
MDC65c		Pallic	6.2	**11**	101	4.1	0.39	1.1	18.5	n.d.	15.4	11
MDC66a	Vineyard	Brown	7.2	26	53	2.7	0.23	1.3	10.4	n.d.	8.9	12
MDC66b		Brown	7	31	122	4	0.36	1.2	**2.9**	n.d.	1.5	11
MDC66c		Brown	6.8	**15**	153	4	0.38	1.1	8.9	n.d.	6.9	11
MDC69a	Vineyard	Pallic	6.2	**37**	86	2.7	0.26	1.3	8.3	n.d.	6.4	10
MDC69b		Pallic	6.4	**43**	124	4	0.41	**1.4**	**5.0**	n.d.	4.7	10
MDC69c		Pallic	6.6	21	145	4	0.41	1.1	10.3	n.d.	7.9	10
MDC70a	Vineyard	Recent	6.7	**16**	72	2.1	0.22	1.3	8.5	n.d.	6.8	10
MDC70b		Recent	6.6	23	122	3.9	0.4	**1.4**	**2.2**	n.d.	<1	10
MDC70c		Recent	6.5	**7**	131	3.9	0.41	1.19	9.6	n.d.	6.7	10

MDC71	Cropping	Brown	5.9	28	84	2.8	0.31	1.39	7.6	**1.02**	6.1	9
MDC72	Cropping	Pallic	6	22	88	3.1	0.32	1.31	8.9	**1.10**	7.4	10
MDC73	Drystock	Brown	5.3	**13**	149	4.9	0.47	1.22	7.5	n.d.	5.4	10
MDC74	Dairy	Recent	5.5	26	242	7.3	0.69	0.83	12.3	n.d.	9.5	11
MDC75	Dairy	Recent	5.8	**15**	183	5.9	0.56	1.03	**2.6**	n.d.	<1	11

4.4 Total Nitrogen

Nitrogen is an essential major nutrient for plants and animals, and organic matter N is an important measure of soil fertility. Typically in topsoils, organic matter N comprises more than 90% of the total N. However, organic matter N needs to be mineralised to inorganic forms (i.e. ammonium and nitrate) by soil microbes before it can be utilised by plants, and also lost from soil by leaching.

All sites had total N concentrations within the acceptable target range for their respective landuse activity (Table 3).

4.5 Carbon to Nitrogen ratio

The balance of C to N in soil is termed the C-N ratio (C:N). This ratio is important as a guide to the state of decomposition or likely ease of decomposition and mineralisation of nutrients e.g. nitrate and ammonium from organic residues in soils, and is a measure of organic matter quality. It is therefore also a guide to the risk of N mobility (nitrate leaching) in soil.

Although there are no specific soil quality target ranges for the C:N ratio, results were in the range generally considered acceptable for that landuse (Table 3). For example, the C:N ratios measured pasture sites were between 10:1 up to 12:1, which is typical of long term pasture soils. This reflects a generally moderate to high soil N status (Table 3), usually a result of many years of N-fixation by white clover, fertiliser inputs, deposition by grazing stock, and microbial incorporation into soil organic matter (Sparling et al., 2001).

4.6 Anaerobically mineralisable nitrogen

Anaerobically mineralisable nitrogen is a measure of the amount of N that can be supplied to plants through the decomposition of soil organic matter by soil microbes. It is a useful measure of soil organic matter quality in terms of its ability to store N. However, the amount of AMN has also been found to correspond with the amount of soil microbial biomass – hence it is also a useful indicator of microbial activity in soils (Myrold, 1987). All sites had AMN contents within their acceptable target ranges for their respective landuse (Table 3).

4.7 Olsen P

Phosphorus is an essential nutrient for both plants and animals. Only a small amount of the total P in soil is in forms able to be taken up by plants (plant available P). The Olsen P method is a chemical extractant that provides a reasonable estimate of the amount of plant-available P by measuring phosphate in soil solution and exchange surfaces.

Two of the cropping sites (MDC61, MDC64) and one of the vineyard sites (MDC69) had Olsen P values above the target range (Table 3). There has been extensive national and international research to show that as soil P concentrations increase, the risk to waterways can also increase (McDowell et al. 2003; McDowell et al. 2004). On the back of these findings, a range of P mitigation strategies have been identified and tested to minimise P loss from soil to water. Some of these include achieving the optimal soil P test, use of low soluble P fertilisers, sediment traps, grass buffer strips, constructed wetlands, and application of amendments to sorb P in soil and drainage water (McDowell, 2012). Regular soil testing, and implementation of nutrient budget and management plans will help minimise excessive nutrient accumulation in soils and potential losses from soils and this should be advocated to land managers.

In comparison one of the dairy sites (MDC75), one of the drystock sites (MDC73) and parts of three of the vineyard sites (MDC65, MDC66 and MDC70) had Olsen P values below concentrations considered optimal for maximum pasture/crop production. Phosphorus concentrations in soils can be increased relatively easily by the application of phosphate fertilisers to soil, hence these low values are not of any environmental concern but may impact on optimal crop or pasture production.

4.8 Bulk density

Bulk density is the weight of soil in a specified volume and provides a measure of how loose or compacted a soil is. Loose soils may be subject to increased risk of erosion, are subject to rapid drying, and plant roots may find it difficult to get purchase and absorb water and nutrients. In contrast, compacted soils have poor aeration and are slow draining.

All sites had bulk density values within their acceptable target ranges for their respective landuse with the exception of four cropping sites (MDC61, MDC62, MDC63, MDC64) and the wheel track of two of the vineyard sites (MDC69, MDC70) which exceeded the upper range (Table 3). The high bulk density at the cropping site is consistent with the results found previously for this land use across Marlborough (Gray 2013). It is likely in part related to the relatively low total C content in this soil which was at the lower boundary of the desired range as discussed in 4.3. However, it is also recognised that some Pallic soils have a high slaking potential and potential for soil structural collapse (Hewitt, 2010). In combination with the tracking of heavy machinery in cropping operations, these factors have likely significantly contributed to elevated bulk density.

At vineyard sites, soils were sampled from the vine, wheel track zone and middle of the inter-row in an attempt to capture the effects of how these different zones are managed within a vineyard. Clearly the high bulk density values in the wheel track zone are related to vehicle traffic which is subject to machinery movement to undertake activities such as mowing, spraying, harvesting and pruning.

4.9 Macroporosity

Macroporosity is a measure of the proportion of large pores in the soil and is, along with bulk density, an indicator of soil compaction. Macropores are important for diffusion of air into soil, extension of roots down into the soil and the drainage of water. Typically macropores are the first to be lost when the soil is compacted.

All but five sites met their target for macroporosity (Table 3). The five sites that did not included one of the cropping sites i.e. MDC64, one of the dairy sites i.e. MDC75 and the wheel track area of three of the vineyard sites, i.e. MDC66b, MDC69b, MDC70b.

Low macroporosity at some dairy pasture sites has been noted previously in Marlborough (Gray, 2011) and has been observed in other regions of New Zealand (Taylor et al., 2010; Fraser and Stevenson, 2011; Sorensen, 2012). The low values are likely related to heavy grazing or grazing under wet conditions where animal treading has effectively reduced the large pore fraction in soils.

Like the dairy sites, low macroporosity on cropping sites has also been widely recognised across NZ (Sorensen, 2010; Drewry et al., 2015). The low macroporosity was likely related to a combination of factors such as the depleted organic C in this soil, its high slaking potential and the use of machinery, especially when soil conditions are too wet for heavy equipment, which has compressed the larger pores. Interestingly low values weren't evident at the other cropping sites, although the soils did show indication of other soil physical instability i.e. low aggregate stability, discussed in section 4.10.

There are a range of potential soil, plant and environmental effects of soil compaction/pugging. One of the most important is the effect on crop/pasture production. For example, animal grazing and treading, particularly in wet conditions, can affect pasture yield directly through leaf burial in mud, crushing, bruising and a reduction in dry matter production (Nie et al., 2001). For both crops and pasture indirect effects include restriction of root penetration and radial growth of roots in dense soils, reduced aeration, increased water logging potential due to slower ability to drain, reduced nutrient availability and also compacted layers that may impact on water infiltration and hence the amount of water storage in a soil. A decrease in the proportion of large pores can also lead to reduced infiltration of water which increases the potential for surface runoff of water. If this runoff contains nutrients i.e. N, P or contaminants i.e. bacteria, this may negatively impact on stream and lake water quality (Ngyen et al., 1998; McDowell et al., 2003).

There are a number of potential mitigation options that can be employed to prevent or minimise the effects of soil compaction. For pasture soils, some practices could include on/off grazing of animals; grazing wetter paddocks before the wet part of the season; maintaining good pasture cover which gives better protection against pugging; installing drainage in some areas; use of feeding platforms and/or standoff areas; decreasing winter stock numbers and moving stock onto well drained soil types off-site. For cropping soils, as discussed maintaining practices that increase soil organic matter are important as well as minimising activity on soils during wet soil conditions that will compress and disrupt soil structure.

4.10 Aggregate stability

Aggregate stability refers to the ability of soil aggregates to resist disruption when forces such as rapid wetting and mechanical abrasion are applied. In general a soil with adequate amounts of soil organic matter will have stable soil aggregates and therefore a higher aggregate stability. A stable soil structure is important to allow water and air movement in soils and to minimise surface erosion.

Aggregate stability measurements were restricted to the cropping sites (Table 3). Although there are no specific target ranges currently available for aggregate stability, generally any value below about 1.5 MWD is considered low and likely to have a negative effect on crop production (Francis et al., 1991). Using this threshold, aggregate stability was well below what is considered desirable for optimal crop growth for five of the six sites.

The low aggregate stability values in the cropping soils are likely to be linked to the relatively low organic matter i.e. total C contents in these soils along with the high slaking potential (Hewitt, 2010). As discussed Pallic soils are usually regarded as unsuitable for continuous cropping to due to their high Structural Vulnerability Index (Hewitt and Shepherd 1997) and therefore potential for soil structural collapse.

4.11 Trace elements

Trace elements accumulate in soils either naturally through weathering of minerals contained in the soil parent material or from anthropogenic sources. While many trace elements are essential for healthy plant and animal growth, i.e. Cu and Zn, at high concentrations in soils these can have a negative impact on soil fertility and plant and animal health. Furthermore, some trace elements, i.e. Cd and As are not required by plants and/or animals, with their accumulation having a potential negative impact. In some cases, there is potential for trace elements to accumulate in the human food chain.

Table 4 summarises trace element concentrations in soils. The concentrations are similar to those found in soils at other monitoring sites in other regions of New Zealand including those found previously in Marlborough (Taylor et al, 2010; Guinto, 2011; Sorensen; 2012; Curran-Cournane and Taylor, 2012; Gray, 2013; Lowe Environmental Impact, 2013). Concentrations are similar to typical background concentrations found in New Zealand soils and well within suggested upper limits for trace elements in soils as suggested by the New Zealand Water and Waste Association (NZWWA, 2003) limits given in Appendix A.

All but one sample (MDC74; 0.67 mg kg^{-1}) had soil cadmium concentrations within thresholds developed as part of a Tiered Fertiliser Management System (TFMS) outlined in the New Zealand Cadmium Management Strategy (MPI, 2011).

The TFMS is a system for linking soil Cd concentrations to different types of management action. For soils with Cd concentrations up to 0.6 mg kg^{-1} (Tier 1) while there are no limits on phosphate fertiliser application, there is a recommendation that soils are tested for Cd every five years. For soils which exceed 0.6 mg kg^{-1} but are below 1 mg kg^{-1} (Tier 2), phosphate fertiliser application rates are restricted to a specific set of products and application rates to manage Cd accumulation to ensure Cd concentrations don’t exceed acceptable thresholds within the next 50 years. For soils which exceed 1 mg kg^{-1} but are below 1.4 mg kg^{-1} (Tier 3), application rates are further managed by use of a Cd balance program to ensure that Cd does not exceed an acceptable threshold within 50 years. While the monitoring of soil Cd is the responsibility of Regional Councils, the implementation of these strategies is the responsibility of the fertiliser industry.

Table 4. Trace element concentrations (mg kg^{-1}) in soils sampled in the Marlborough Region 2015.

Site code	Landuse	Zn	Cu	Cr	As	Pb	Ni	Hg	Cd
		(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
MDC61	Cropping	72	12	27	4.5	11	21	< 0.11	0.14
MDC62	Cropping	50	13	22	5.8	10	20	< 0.10	0.10
MDC63	Cropping	58	10	22	4.4	9	20	< 0.11	0.10
MDC64	Cropping	68	11	29	3.8	10	24	< 0.10	0.16
MDC65a	Vineyard	80	12	28	4.3	10	20	< 0.11	0.13
MDC65b		73	11	33	4.2	10	23	< 0.11	0.13
MDC65c		71	11	29	4	10	20	< 0.10	0.12
MDC66a	Vineyard	94	22	19	5.7	11	16	< 0.10	0.18
MDC66b		74	20	22	5.4	10	18	< 0.10	0.19
MDC66c		77	21	19	5.1	11	17	< 0.10	0.22
MDC69a	Vineyard	75	18	23	6.2	17	19	< 0.11	0.17
MDC69b		70	18	26	6.3	21	20	< 0.11	0.19
MDC69c		73	18	24	6.6	16	19	< 0.10	0.16
MDC70a	Vineyard	69	21	27	5.5	12	19	< 0.11	0.13
MDC70b		59	20	26	5.2	12	21	< 0.10	0.16
MDC70c		59	22	22	5.3	12	17	< 0.11	0.16
MDC71	Cropping	59	6	24	2.7	8	16	< 0.11	0.15
MDC72	Cropping	61	7	15	3.1	9	12	< 0.10	0.15
MDC73	Drystock	71	18	21	6	10	21	< 0.11	0.15
MDC74	Dairy	65	15	26	5	14	10	< 0.11	0.67
MDC75	Dairy	63	15	31	5	13	14	< 0.11	0.43

5. Changes since 2010

It is recommended that to obtain reliable, long-term detection and prediction of trends in soil quality, at least three and preferably five points along a time sequence should be obtained (Wheeler and Edmeades, 1991). Because only one set of data has been collected since the sites were established and sampled in 2010, trends cannot be determined. Nonetheless, soil quality values measured at two sample dates can provide a useful snapshot of change over the 5 years interval. The mean change in soil quality indicators for soils sampled in 2010 and again in 2015 are presented in Table 5. It should be noted that because soils were only sampled in the zone of the wheel track of vineyard sites in 2010, comparisons were made to soils sampled from this zone in 2015.

There were three statistically significant changes in soil indicators between sampling dates. For the cropping sites overall there was significant increase in aggregate stability. Whilst values are still on the low side for five of the six sites, the increase is a positive outcome. As discussed, reduced soil structural stability is a concern across intensive cropping sites in all parts of New Zealand, and can potentially result in a range of both production and environmental issues.

For the vineyards sites there was an increase in soil Olsen P under the vine and a decrease in soil bulk density in the wheel track area. With the exception of one site with an elevated Olsen P, values were low or within the accepted range. Hence the increase currently isn't a concern. The decrease in soil bulk density is positive in the wheel track area, although values are still elevated at some sites. As discussed, soil compaction is a concern across intensive landuse in all parts of New Zealand, and can potentially result in a range of both production and environmental issues.

Table 5. Mean changes in soil quality indicators for sites sampled in 2010 and 2015. * significant level of change (*$p < 0.05$).

Site code	Landuse	pH	Olsen P	AMN	Total C	Total N	Bulk density	Macroporosity	Agg Stab	Cd
			(mg L^{-1})	(mg kg^{-1})	(%)	(%)	(Mg m^{-3})	-10k Pa (%v/v)	(mwd)	(mg kg^{-1})
MDC61	Cropping	-0.7	-16	-29	-1.5	-0.15	-0.08	9.1	1.16	-0.06
MDC62	Cropping	-0.2	-4	-16	-0.5	-0.05	-0.04	1.2	0.38	0.00
MDC63	Cropping	-0.3	2	-18	-0.5	-0.06	-0.12	6.6	0.6	-0.02
MDC64	Cropping	-0.6	4	-2	-0.1	-0.03	0.07	0.9	1	-0.02
MDC71	Cropping	0.1	13	28	0.2	0.03	0.03	-2.6	0.46	-0.02
MDC72	Cropping	0.1	4	37	0.3	0.03	-0.03	-4.2		-0.01
	Mean	-0.3	0.5	0	-0.4	-0.04	-0.03	1.8	**0.7***	-0.02
MDC74	Dairy	-0.1	-12	40	-0.5	0.02	-0.03	1.3		-0.35
MDC75	Dairy	0.0	-6	-1	-0.1	0.01	0.14	-8		-0.10
	Mean	-0.05	-9	19.5	-0.3	0.02	0.05	-3.3		-0.23
MDC65	Vineyard - vine	-0.3	6	12	0.1	-0.05	0.03	-2.6		0.00
MDC66	Vineyard	0.5	3	-65	0.0	-0.05	0.01	-0.4		-0.07
MDC69	Vineyard	-0.5	1	26	-0.1	-0.04	-0.03	-1.7		0.00
MDC70	Vineyard	0.2	4	23	0.1	0.01	-0.11	-3.3		-0.03
	Mean	-0.02	**3.5***	-1.0	0.03	-0.03	-0.03	-2.0		-0.03
MDC65	Vineyard - wheel	-0.3	7	14	0.0	0	-0.28	10.8		-0.01
MDC66	Vineyard	0.1	6	-33	0.8	0.05	-0.12	-0.9		0.00
MDC69	Vineyard	-0.5	-5	40	0.5	0.02	-0.05	1.7		0.01
MDC70	Vineyard	-0.1	-5	16	0.1	0.01	-0.14	-3.2		0.03
	Mean	-0.20	0.75	9.25	0.35	0.02	**-0.15***	2.1		0.01
MDC73	Drystock	-0.1	1	28	0.9	0.01	0.04	-4.4		0.01

6. Summary

Monitoring has highlighted that there are several soil quality issues under some land use activities in Marlborough, although in the majority of instances these can be reversed with appropriate management.

- An elevated Olsen P value was found at two of the cropping sites and one of the vineyard sites. High soil P has the potential to negatively affect water quality if it enters surface water bodies. Implementation of nutrient budget plans will help minimise excessive nutrient accumulation in soils, while farm management plans can help identify source areas for P accumulation and present site specific mitigation methods that could implemented on farm. These options should be advocated to land managers across all industry sectors.

- Low aggregate stability, high bulk density along with organic matter concentrations at the lower end of the desired target range is also a potential issue at the cropping site. This has resulted in poor soil structure at this site which may potentially negatively affect crop performance and predispose the soil to surface runoff, nutrient loss, erosion and flooding. Management practices that maintain or enhance soil C contents to stabilise and improve soil structure should be encouraged.

- One of the cropping, one of the dairy sites and the wheel track areas of three vineyards sites showed signs of soil compaction i.e. low macroporosity. In the case of the dairy site, the low values are likely related to heavy grazing or grazing under wet conditions where animal treading has effectively reduced the large pore fraction in soils. While low macroporosity at the cropping and vineyard sites, is likely related the use of machinery, especially when soil conditions are too wet for heavy equipment, and this is exacerbated in cropping soils by the depleted soil C content and the inherent physical instability of some Pallic soils. Low macroporposity values have been shown to negatively affect a range of soil physical/chemical processes which can in turn reduce pasture dry matter production. Furthermore, it can also increase the potential for surface run-off and provide a pathway for nutrient (N and P) and microbe loss to surface waters and reduce water quality. There are a number of potential mitigation methods that can be effectively employed to prevent or minimise the effects of compaction.

- There were three statistically significant changes in soil indicators between sampling dates. For the cropping sites overall there was significant increase in aggregate stability and for the vineyards sites there was an increase in soil Olsen P under the vine and a decrease in soil bulk density in the wheel track area.

7. Recommendations

- Future work should focus on re-sampling these and other established sites to obtain as a minimum four or five repeat samples to determine whether there are any discernable trends in soil quality indicators.

- Many of the trends in declining soil quality can be offset by better land management practices i.e. nutrient budgets/nutrient management plans, changing grazing practices during high soil moisture etc. Council should continue to educate land managers on strategies to protect the environment while achieving an economic return from the land.

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9. Appendix A

Soil quality indicator target (or optimal) ranges from Hill and Sparling (2009) are outlined in the tables below. Numbers in bold indicate the acceptable range. Guideline values for trace element concentrations in soil, adapted from NZWWA (2003).

Olsen P target ranges from Hill and Sparling (2009) are no longer used. Updated targets from Taylor (2011) are now used and presented below.

Bulk density target ranges (t/m^3 or Mg/m^3)

	Very loose	Loose	Adequate	Compact	Very compact	
Semi-arid, Pallic and Recent soils	0.3	**0.4**	0.9	1.25	**1.4**	1.6
Allophanic soils		**0.3**	0.6	0.9	**1.3**	
Organic soils		**0.2**	0.4	0.6	**1.0**	
All other soils	0.3	**0.7**	0.8	1.2	**1.4**	1.6

Notes:

Applicable to all land uses

Target ranges for cropping and horticulture are poorly defined

Macroporosity target ranges (% @ -10 kPa)

	Very low	Low	Adequate	High	
Pastures, cropping and horticulture	0	6	**10**[1]	30	40
Forestry	0	**8**	10	30	40

Notes:
1: Revised based on Mackay et al (2006)
Applicable to all Soil orders

Total carbon target ranges (% w/w)

	Very depleted	Depleted	Normal	Ample	
Allophanic	0.5	**3**	4	9	**12**
Semi-arid, Pallic and Recent	0	**2**	3	5	**12**
Organic	exclusion				
All other Soil Orders	0.5	**2.5**	3.5	7	**12**

Notes:

Applicable to all Soil Orders
Organic soils by definition must have >15% total C content, hence C content is not a quality indicator for that order and is defined as an "exclusion" Target ranges for cropping and horticulture are poorly defined

Total nitrogen target ranges (% w/w)

	Very depleted	Depleted	Normal	Ample	High	
Pasture	0	**0.25**	0.35	0.65	**0.70**	1.0
Forestry	0	**0.10**	0.20	0.60	**0.70**	
Cropping and horticulture	exclusion					

Notes:

Applicable to all Soil Orders

Target ranges for cropping and horticulture are not specified as target values will depend on the specific crop grown

Anaerobic mineralisable nitrogen (AMN) target ranges (mg/kg)

	Very low	Low	Adequate	Ample	High	Excessive	
Pasture	25	**50**	100	200	200	**250**	300
Forestry	5	**20**	40	120	150	**175**	200
Cropping and horticulture	5	**20**	100	150	150	**200**	225

Notes:

Applicable to all Soil Orders

Target ranges for cropping and horticulture are poorly defined

Soil pH target ranges

	Very acid	Slightly acid	Optimal	Sub-optimal	Very alkaline	
Pastures on all soils except Organic	4	**5**	5.5	6.3	**6.6**	8.5
Pastures on Organic soils	4	**4.5**	5	6	**7.0**	
Cropping and horticulture on all soils except	4	**5**	5.5	7.2	**7.6**	8.5
Cropping and horticulture on Organic	4	**4.5**	5	7	**7.6**	
Forestry on all soils except Organic		**3.5**	4	7	**7.6**	
Forestry on Organic soils	exclusion					

Notes:

Applicable to all Soil Orders

Target ranges for cropping and horticulture are general averages and target values will depend on the specific crop grown

Exclusion is given for forestry on organic soils as this combination is unlikely because of wind throw

Olsen P target ranges (units not reported) from Taylor (2011)

Landuse	Soil type	Suggested Olsen P target
Pasture, horticulture and cropping	Volcanic	20-50
Pasture, horticulture and cropping	Sedimentary and Organic soils	20-35
Pasture, horticulture and cropping	Raw sands and Podzols with low AEC	5
Pasture, horticulture and cropping	Raw sands and Podzols with medium AEC and above AEC	15-25
Pasture, horticulture and cropping	Other soils	20-45
Pasture, horticulture and cropping	Hill country	15-20
Forestry	All soils	5-30

Guideline values for trace element concentrations in soil, adapted from NZWWA (2003)

Trace element	Soil Limit (mg kg^{-1})
Arsenic (As)	20
Cadmium (Cd)	1
Chromium (Cr)	600
Copper (Cu)	100
Lead (Pb)	300
Nickel (Ni)	60
Zinc (Zn)	300

Aggregate stability data 2015 – Plant and Food Research

Sample label on ice cream lid	Site Names	Rep	Mean Weight Diameter of aggregates (mm)	% of aggregates >1mm
20155678	SoE Soils Site 61 15m 0-10cm	0	1.59	62.16
20155681	SoE Soils Site 61 30m 0-10cm	0	1.57	56.46
20155685	SoE Soils Site 61 45m 0-10cm	0	1.61	56.95
20155690	SoE Soils Site 62 15m 0-10cm	0	0.88	27.07
20155693	SoE Soils Site 62 30m 0-10cm	0	0.88	27.50
20155697	SoE Soils Site 62 45m 0-10cm	0	0.84	24.75
20155702	SoE Soils Site 63 15m 0-10cm	0	1.11	34.94
20155705	SoE Soils Site 63 30m 0-10cm	0	0.86	25.98
20155709	SoE Soils Site 63 45m 0-10cm	0	0.99	31.72
20155714	SoE Soils Site 64 15m 0-10cm	0	1.44	53.16
20155717	SoE Soils Site 64 30m 0-10cm	0	1.41	50.90
20155721	SoE Soils Site 64 45m 0-10cm	0	1.27	45.84
20155870	SoE Soils Site 71 15m 0-10cm	0	0.92	30.24
20155874	SoE Soils Site 71 30m 0-10cm	0	0.96	30.67
20155877	SoE Soils Site 71 45m 0-10cm	0	1.19	39.50
20155929	SoE Soils Site 72 15m 0-10cm	0	0.94	29.51
20155933	SoE Soils Site 72 30m 0-10cm	0	1.19	39.80
20155936	SoE Soils Site 72 45m 0-10cm	0	1.10	36.27

Soil moisture release data 2015 – Landcare Research

Marlborough District Council Soil Quality 2015/16
Moisture Release Results
Job: 682208-0107
January 2016

Lab Number	Client ID	Transect Position	Client Sample Number	Sampled Liner Number	Initial Water Content (%, w/w)	Dry Bulk Density (t/m3)	Particle Density (t/m3)	Total Porosity (%, v/v)	Macro Porosity (%, v/v)	Air Filled Porosity (%, v/v)	Vol. WC 5kPa (%, v/v)	Vol. WC 10kPa (%, v/v)	Vol. WC 100kPa (%, v/v)	Vol. WC 1500kPa (%, v/v)	Readily Available Water (%, v/v)	Total Available Water (%, v/v)
HP6527a	Site 61	15m	2015 5679	1718	14.8	1.50	2.64	43.3	6.0	8.7	37.4	34.6	26.9	16.5	7.6	18.1
HP6527b		30m	2015 5683	1086	16.6	1.48	2.64	43.8	7.9	9.4	35.9	34.4	27.7	16.6	6.6	17.7
HP6527c		45m	2015 5686	1067	16.7	1.42	2.64	46.1	9.8	12.1	36.3	34.0	26.2	16.1	7.8	17.9
HP6528a	Site 62	15m	2015 5691	1629	19.1	1.46	2.67	45.4	3.3	9.4	42.1	36.0	25.9	11.8	10.1	24.2
HP6528b		30m	2015 5695	1091	19.1	1.42	2.68	47.0	10.1	13.5	36.9	33.5	25.1	11.2	8.4	22.2
HP6528c		45m	2015 5698	1022	18.4	1.39	2.68	48.1	12.9	16.7	35.2	31.4	23.4	10.6	8.1	20.9
HP6529a	Site 63	15m	2015 5702	1540	18.6	1.50	2.66	43.5	2.4	6.5	41.1	37.0	28.9	14.9	8.0	22.1
HP6529b		30m	2015 5707	1031	18.4	1.50	2.66	43.7	2.7	7.3	41.0	36.4	26.7	14.7	9.7	21.7
HP6529c		45m	2015 5709	1670	19.6	1.43	2.66	46.3	9.8	12.4	36.5	33.9	27.8	14.3	6.1	19.6
HP6530a	Site 64	15m	2015 5715	1727	22.9	1.48	2.62	43.5	4.8	6.6	38.7	36.9	30.6	19.4	6.3	17.5
HP6530b		30m	2015 5719	1218	26.3	1.43	2.64	45.7	6.7	8.3	39.0	37.4	31.9	18.8	5.5	18.6
HP6530c		45m	2015 5722	1270	23.2	1.56	2.64	40.9	1.0	2.7	39.9	38.2	32.3	20.7	5.8	17.4
HP6531a	Site 65a	15m	2015 5727	1007	34.1	1.22	2.62	53.4	9.8	13.0	43.6	40.4	32.7	16.1	7.8	24.3
HP6531b		30m	2015 5731	1109	30.4	1.31	2.61	49.9	8.0	10.0	41.8	39.9	33.0	16.9	6.9	23.1
HP6531c		45m	2015 5734	1648	26.9	1.30	2.62	50.3	10.1	11.9	40.1	38.4	30.7	18.1	7.7	20.3
HP6532a	Site 65b	15m	2015 5739	1317	35.9	1.17	2.60	55.2	10.0	13.3	45.2	41.9	31.9	16.1	10.0	25.8
HP6532b		30m	2015 5743	1242	36.6	1.21	2.60	53.6	7.2	9.8	46.5	43.8	32.5	16.8	11.3	27.0
HP6532c		45m	2015 5746	1230	35.3	1.06	2.60	59.1	17.3	19.9	41.8	39.2	32.4	14.6	6.9	24.7
HP6533a	Site 65c	15m	2015 5751	1296	35.4	1.11	2.61	57.5	14.1	17.3	43.4	40.2	31.2	14.6	8.9	25.5
HP6533b		30m	2015 5755	1195	44.8	1.00	2.59	61.4	16.1	19.0	45.3	42.4	33.0	13.6	9.4	28.8
HP6533c		45m	2015 5758	1620	38.7	1.04	2.59	59.9	16.0	19.3	43.9	40.6	32.8	14.3	7.8	26.3
HP6534a	Site 66a	15m	2015 5763	1640	30.4	1.33	2.70	50.8	4.0	5.5	46.7	45.3	40.1	22.1	5.1	23.2
HP6534b		30m	2015 5767	1527	30.5	1.25	2.70	53.7	11.6	13.1	42.1	40.6	35.6	18.7	5.0	21.8
HP6534c		45m	2015 5770	1596	29.6	1.26	2.70	53.3	11.0	12.5	42.2	40.8	35.7	19.0	5.0	21.7
HP6535a	Site 66b	15m	2015 5775	1613	39.4	1.21	2.64	54.2	1.0	2.6	53.2	51.6	44.5	21.4	7.1	30.2
HP6535b		30m	2015 5779	1078	36.6	1.25	2.66	53.0	2.0	3.5	51.1	49.5	43.3	22.0	6.2	27.5
HP6535c		45m	2015 5782	1582	43.5	1.14	2.66	57.0	1.4	2.5	55.6	54.5	46.4	18.7	8.1	35.7
HP6536a	Site 66c	15m	2015 5787	1617	42.9	1.09	2.65	58.7	4.8	7.1	53.9	51.6	43.4	20.2	8.2	31.3
HP6536b		30m	2015 5791	1187	41.5	1.12	2.65	57.8	6.7	8.6	51.0	49.2	42.9	19.3	6.3	29.9
HP6536c		45m	2015 5794	1232	34.1	1.16	2.68	56.6	9.1	11.1	47.5	45.5	38.0	19.1	7.5	26.4
HP6537a	Site 69a	15m	2015 5799	1626	33.7	1.25	2.64	52.8	5.3	7.8	47.5	45.0	38.5	18.7	6.5	26.3
HP6537b		30m	2015 5803	1377	32.5	1.30	2.63	50.7	4.7	6.5	46.0	44.2	39.4	17.6	4.8	26.5
HP6537c		45m	2015 5806	1062	27.3	1.34	2.66	49.6	9.3	10.6	40.3	39.0	32.3	16.2	6.7	22.8
HP6538a	Site 69b	15m	2015 5811	1395	36.0	1.29	2.62	51.0	<1	3.0	50.4	48.0	41.9	19.0	6.1	29.0
HP6538b		30m	2015 5815	1734	27.2	1.41	2.63	46.6	3.7	5.0	42.9	41.6	37.1	19.1	4.4	22.5
HP6538c		45m	2015 5818	1246	29.1	1.35	2.64	48.7	5.6	7.0	43.1	41.7	35.0	17.6	6.7	24.1
HP6539a	Site 69c	15m	2015 5823	1561	37.2	1.16	2.62	55.9	5.1	8.0	50.8	47.9	41.1	18.6	6.8	29.3
HP6539b		30m	2015 5827	1291	39.8	1.08	2.60	58.4	11.8	13.6	46.6	44.8	38.4	16.5	6.4	28.3
HP6539c		45m	2015 5830	1608	45.2	1.04	2.59	59.7	6.8	9.2	52.9	50.5	43.3	16.8	7.2	33.7
HP6540a	Site 70a	15m	2015 5835	1056	25.9	1.39	2.66	47.8	7.8	9.7	40.1	38.1	32.0	15.7	6.1	22.4
HP6540b		30m	2015 5839	1588	30.0	1.33	2.66	50.1	6.8	8.3	43.3	41.8	37.4	17.4	4.4	24.4
HP6540c		45m	2015 5842	1020	33.7	1.30	2.65	51.0	5.7	7.5	45.4	43.5	39.0	16.2	4.5	27.3
HP6541a	Site 70b	15m	2015 5847	1392	32.9	1.37	2.62	47.5	<1	<1	50.2	48.6	40.1	17.7	8.5	30.9
HP6541b		30m	2015 5851	1368	34.4	1.32	2.61	49.3	<1	<1	49.6	48.4	41.6	19.3	6.8	29.1
HP6541c		45m	2015 5854	1023	29.0	1.41	2.64	46.7	<1	2.2	45.7	44.5	39.3	18.6	5.2	25.9
HP6542a	Site 70c	15m	2015 5859	1539	36.6	1.17	2.60	55.2	7.4	10.6	47.8	44.6	33.9	15.3	10.7	29.3
HP6542b		30m	2015 5863	1176	35.9	1.19	2.61	54.3	6.6	10.1	47.7	44.2	33.0	15.9	11.2	28.4
HP6542c		45m	2015 5866	1279	36.3	1.22	2.62	53.4	6.2	8.1	47.2	45.3	37.3	16.7	8.1	28.6
HP6543a	Site 71	15m	2015 5871	1241	26.3	1.31	2.60	49.8	8.4	10.4	41.4	39.4	33.3	15.5	6.1	23.9
HP6543b		30m	2015 5875	1282	23.2	1.44	2.59	44.6	6.4	7.6	38.2	37.0	32.7	17.5	4.2	19.4
HP6543c		45m	2015 5878	1278	27.5	1.42	2.60	45.4	3.5	4.7	41.9	40.7	36.1	16.7	4.6	23.9
HP6544a	Site 72	15m	2015 5930	1248	28.3	1.28	2.59	50.8	10.8	12.6	40.0	38.2	33.1	16.6	5.2	21.7
HP6544b		30m	2015 5934	1041	23.1	1.42	2.59	45.1	7.6	8.8	37.5	36.3	31.5	16.6	4.8	19.7
HP6544c		45m	2015 5937	1044	36.2	1.24	2.58	51.9	3.7	5.2	48.2	46.7	41.6	14.9	5.2	31.9
HP6545a	Site 73	15m	2015 5942	1700	43.2	1.15	2.66	56.9	2.6	4.4	54.3	52.5	41.7	19.2	10.8	33.3
HP6545b		30m	2015 5946	1600	33.1	1.25	2.64	52.6	5.3	7.6	47.4	45.0	36.1	19.3	8.9	25.8
HP6545c		45m	2015 5949	1032	30.9	1.26	2.66	52.6	8.4	10.5	44.2	42.1	34.0	16.7	8.1	25.4
HP6546a	Site 74	15m	2015 5954	1042	64.1	0.84	2.48	66.0	9.7	11.9	56.4	54.1	44.3	28.9	9.7	25.2
HP6546b		30m	2015 5958	1208	64.2	0.83	2.55	67.5	11.5	14.6	55.9	52.9	44.2	27.5	8.7	25.4
HP6546c		45m	2015 5961	1115	70.5	0.83	2.51	67.1	7.4	10.5	59.7	56.6	46.7	28.3	9.9	28.3
HP6547a	Site 75	15m	2015 5966	1726	62.0	0.96	2.58	62.6	<1	2.6	62.4	60.0	51.6	29.0	8.4	31.0
HP6547b		30m	2015 5970	1026	65.4	0.94	2.57	63.3	<1	<1	65.4	62.8	51.6	27.9	11.2	34.9
HP6547c		45m	2015 5973	1236	46.2	1.17	2.66	56.1	<1	2.6	55.4	53.5	45.5	20.6	8.0	32.9

Note: n of -5 kPa, for consistency with the National Soils Database of New Zealand (NSD).
n be referred to as Macro-porosity. It is important to be aware what tension has been used, paticularly with historical or NSD data.

<1 indicate instances where the samples were right on the limit of the methodology capability.
sity and have presented as negative numbers following calculation of the raw data.
hence the macroporosity data has been adjusted to simply indicate samples with extremely low figures.

le was in a bag labelled 2015 5706 rather than the expected 2015 5707.

Checked by: ohn Claydon
Laboratory Manager

Analyst: DT

Soil chemical data 2015 – Hills Laboratory

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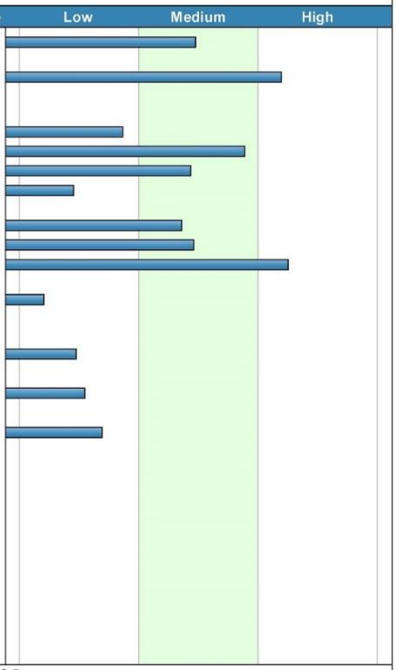
ANALYSIS REPORT — Page 1 of 24

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155688 **Lab Number:** 1486113.1
Sample Type: SOIL Mixed Pasture (S1)

Analysis	Units	Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.2
Olsen Phosphorus	mg/L	42	20 - 30
Anion Storage Capacity (estimated)*	%	27	
Potassium	me/100g	0.37	0.40 - 0.60
Calcium	me/100g	9.3	4.0 - 10.0
Magnesium	me/100g	1.26	1.00 - 1.60
Sodium	me/100g	0.09	0.20 - 0.50
CEC	me/100g	17	12 - 25
Total Base Saturation	%	66	50 - 85
Volume Weight	g/mL	1.06	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	70	150 - 250
Anaerobically Mineralisable N*	µg/g	44	
Organic Matter*	%	3.3	7.0 - 17.0
Total Carbon*	%	1.9	
Total Nitrogen*	%	0.21	0.30 - 0.60
C/N Ratio*		9.2	
Anaerobically Mineralisable N/Total N Ratio*	%	2.1	3.0 - 5.0
'Total' Zinc*	mg/kg	72	
'Total' Copper*	mg/kg	12	
'Total' Chromium*	mg/kg	27	
'Total' Arsenic*	mg/kg	4.5	
'Total' Lead*	mg/kg	10.7	
'Total' Nickel*	mg/kg	21	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.14	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 2.2 Ca 56 Mg 7.6 Na 0.5	
MAF Units		K 8 Ca 12 Mg 30 Na 4	



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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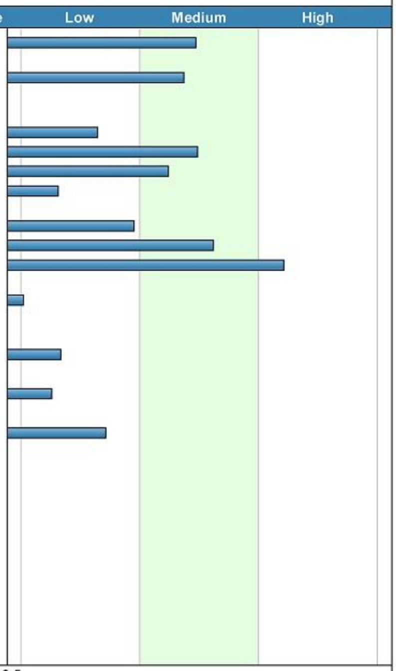
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443 BLENHEIM 7240	**Date Registered:**	08-Oct-2015
		Date Reported:	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155700 **Lab Number:** 1486113.2
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.2
Olsen Phosphorus	mg/L	24	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	0.31	0.40 - 0.60
Calcium	me/100g	6.9	4.0 - 10.0
Magnesium	me/100g	1.15	1.00 - 1.60
Sodium	me/100g	0.06	0.20 - 0.50
CEC	me/100g	12	12 - 25
Total Base Saturation	%	72	50 - 85
Volume Weight	g/mL	1.05	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	52	150 - 250
Anaerobically Mineralisable N*	µg/g	33	
Organic Matter*	%	2.3	7.0 - 17.0
Total Carbon*	%	1.4	
Total Nitrogen*	%	0.15	0.30 - 0.60
C/N Ratio*		9.0	
Anaerobically Mineralisable N/Total N Ratio*	%	2.2	3.0 - 5.0
'Total' Zinc*	mg/kg	50	
'Total' Copper*	mg/kg	13	
'Total' Chromium*	mg/kg	22	
'Total' Arsenic*	mg/kg	5.8	
'Total' Lead*	mg/kg	10.2	
'Total' Nickel*	mg/kg	20	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.10	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 2.6 Ca 59	Mg 9.7 Na 0.5
MAF Units		K 7 Ca 9	Mg 27 Na 3



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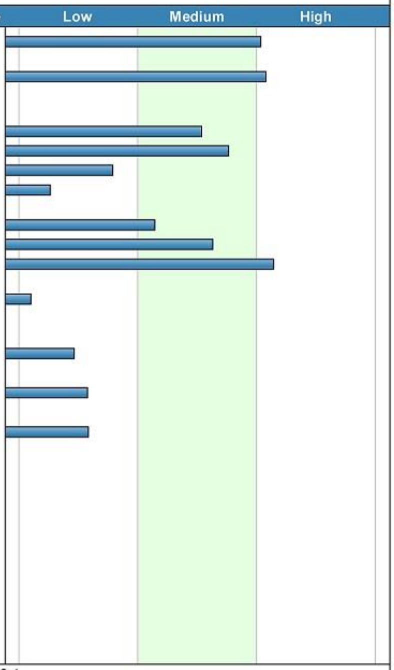
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155712 **Lab Number:** 1486113.3
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.2	5.8 - 6.2
Olsen Phosphorus	mg/L	35	20 - 30
Anion Storage Capacity (estimated)*	%	20	
Potassium	me/100g	0.51	0.40 - 0.60
Calcium	me/100g	8.6	4.0 - 10.0
Magnesium	me/100g	0.85	1.00 - 1.60
Sodium	me/100g	0.05	0.20 - 0.50
CEC	me/100g	14	12 - 25
Total Base Saturation	%	72	50 - 85
Volume Weight	g/mL	1.04	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	60	150 - 250
Anaerobically Mineralisable N*	µg/g	39	
Organic Matter*	%	3.2	7.0 - 17.0
Total Carbon*	%	1.9	
Total Nitrogen*	%	0.22	0.30 - 0.60
C/N Ratio*		8.7	
Anaerobically Mineralisable N/Total N Ratio*	%	1.8	3.0 - 5.0
'Total' Zinc*	mg/kg	58	
'Total' Copper*	mg/kg	10	
'Total' Chromium*	mg/kg	22	
'Total' Arsenic*	mg/kg	4.4	
'Total' Lead*	mg/kg	9.3	
'Total' Nickel*	mg/kg	19.8	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.10	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 3.7 Ca 62	Mg 6.1 Na 0.4
MAF Units		K 11 Ca 11	Mg 20 Na 2



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155724 **Lab Number:** 1486113.4
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.2
Olsen Phosphorus	mg/L	38	20 - 30
Anion Storage Capacity (estimated)*	%	23	
Potassium	me/100g	0.29	0.40 - 0.60
Calcium	me/100g	9.7	4.0 - 10.0
Magnesium	me/100g	1.84	1.00 - 1.60
Sodium	me/100g	0.17	0.20 - 0.50
CEC	me/100g	19	12 - 25
Total Base Saturation	%	63	50 - 85
Volume Weight	g/mL	0.86	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	64	150 - 250
Anaerobically Mineralisable N*	µg/g	49	
Organic Matter*	%	4.5	7.0 - 17.0
Total Carbon*	%	2.6	
Total Nitrogen*	%	0.26	0.30 - 0.60
C/N Ratio*		9.8	
Anaerobically Mineralisable N/Total N Ratio*	%	1.9	3.0 - 5.0
'Total' Zinc*	mg/kg	68	
'Total' Copper*	mg/kg	11	
'Total' Chromium*	mg/kg	29	
'Total' Arsenic*	mg/kg	3.8	
'Total' Lead*	mg/kg	10.4	
'Total' Nickel*	mg/kg	24	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.16	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 1.5 Ca 51	Mg 9.7 Na 0.9
MAF Units		K 5 Ca 11	Mg 36 Na 7

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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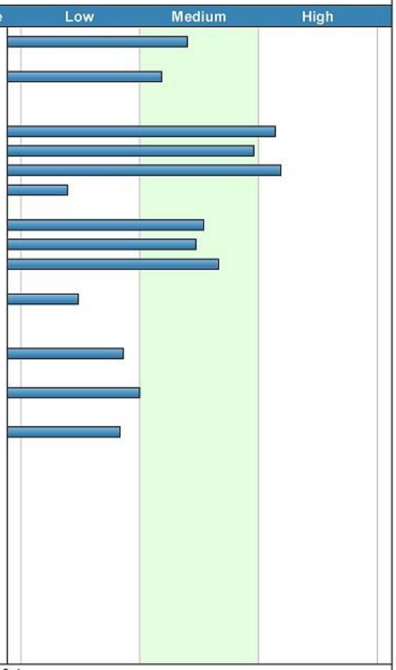
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155736 **Lab Number:** 1486113.5
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.2
Olsen Phosphorus	mg/L	22	20 - 30
Anion Storage Capacity (estimated)*	%	24	
Potassium	me/100g	0.68	0.40 - 0.60
Calcium	me/100g	9.8	4.0 - 10.0
Magnesium	me/100g	2.11	1.00 - 1.60
Sodium	me/100g	0.08	0.20 - 0.50
CEC	me/100g	19	12 - 25
Total Base Saturation	%	67	50 - 85
Volume Weight	g/mL	0.87	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	98	150 - 250
Anaerobically Mineralisable N*	µg/g	75	
Organic Matter*	%	6.0	7.0 - 17.0
Total Carbon*	%	3.5	
Total Nitrogen*	%	0.30	0.30 - 0.60
C/N Ratio*		11.7	
Anaerobically Mineralisable N/Total N Ratio*	%	2.5	3.0 - 5.0
'Total' Zinc*	mg/kg	80	
'Total' Copper*	mg/kg	12	
'Total' Chromium*	mg/kg	28	
'Total' Arsenic*	mg/kg	4.3	
'Total' Lead*	mg/kg	9.7	
'Total' Nickel*	mg/kg	19.5	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.13	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 3.6 Ca 51	Mg 11.1 Na 0.4
MAF Units		K 12 Ca 11	Mg 41 Na 3



The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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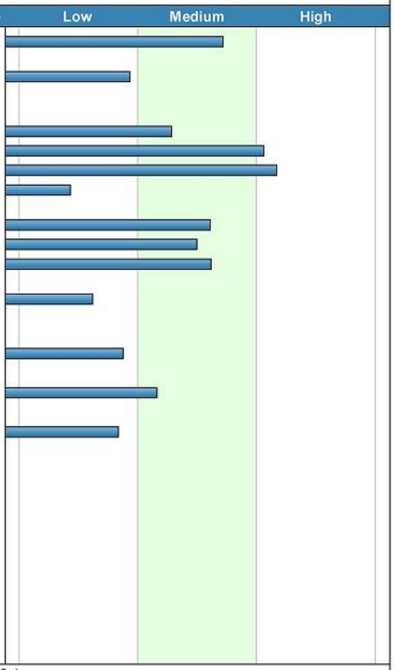
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113	shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015	
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015	
		Quote No:	57142	
		Order No:	4306RRA1	
		Client Reference:	Soil SoE on Sep-2015	
Phone:	03 520 7400	**Submitted By:**	Rachel Rait	

Sample Name: 20155748 **Lab Number:** 1486113.6
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.1	5.8 - 6.2
Olsen Phosphorus	mg/L	19	20 - 30
Anion Storage Capacity (estimated)*	%	25	
Potassium	me/100g	0.46	0.40 - 0.60
Calcium	me/100g	10.9	4.0 - 10.0
Magnesium	me/100g	2.06	1.00 - 1.60
Sodium	me/100g	0.09	0.20 - 0.50
CEC	me/100g	20	12 - 25
Total Base Saturation	%	67	50 - 85
Volume Weight	g/mL	0.85	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	112	150 - 250
Anaerobically Mineralisable N*	µg/g	88	
Organic Matter*	%	6.1	7.0 - 17.0
Total Carbon*	%	3.6	
Total Nitrogen*	%	0.35	0.30 - 0.60
C/N Ratio*		10.2	
Anaerobically Mineralisable N/Total N Ratio*	%	2.5	3.0 - 5.0
'Total' Zinc*	mg/kg	73	
'Total' Copper*	mg/kg	11	
'Total' Chromium*	mg/kg	33	
'Total' Arsenic*	mg/kg	4.2	
'Total' Lead*	mg/kg	9.7	
'Total' Nickel*	mg/kg	23	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.13	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 2.3 Ca 54	Mg 10.3 Na 0.4
MAF Units		K 8 Ca 11	Mg 39 Na 3



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ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155760 **Lab Number:** 1486113.7
Sample Type: SOIL Mixed Pasture (S1)

Analysis	Units	Level Found	Medium Range
pH	pH Units	6.2	5.8 - 6.2
Olsen Phosphorus	mg/L	11	20 - 30
Anion Storage Capacity (estimated)*	%	24	
Potassium	me/100g	0.29	0.40 - 0.60
Calcium	me/100g	11.6	4.0 - 10.0
Magnesium	me/100g	1.98	1.00 - 1.60
Sodium	me/100g	0.18	0.20 - 0.50
CEC	me/100g	20	12 - 25
Total Base Saturation	%	69	50 - 85
Volume Weight	g/mL	0.79	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	120	150 - 250
Anaerobically Mineralisable N*	µg/g	101	
Organic Matter*	%	7.1	7.0 - 17.0
Total Carbon*	%	4.1	
Total Nitrogen*	%	0.39	0.30 - 0.60
C/N Ratio*		10.6	
Anaerobically Mineralisable N/Total N Ratio*	%	2.6	3.0 - 5.0
'Total' Zinc*	mg/kg	71	
'Total' Copper*	mg/kg	11	
'Total' Chromium*	mg/kg	29	
'Total' Arsenic*	mg/kg	4.0	
'Total' Lead*	mg/kg	9.9	
'Total' Nickel*	mg/kg	19.8	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.12	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 1.4 Ca 57	Mg 9.8 Na 0.9
MAF Units		K 5 Ca 11	Mg 35 Na 6

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Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155772 **Lab Number:** 1486113.8
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	7.2	5.8 - 6.2
Olsen Phosphorus	mg/L	26	20 - 30
Anion Storage Capacity (estimated)*	%	24	
Potassium	me/100g	0.55	0.40 - 0.60
Calcium	me/100g	12.9	4.0 - 10.0
Magnesium	me/100g	1.34	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	16	12 - 25
Total Base Saturation	%	90	50 - 85
Volume Weight	g/mL	0.93	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	75	150 - 250
Anaerobically Mineralisable N*	µg/g	53	
Organic Matter*	%	4.7	7.0 - 17.0
Total Carbon*	%	2.7	
Total Nitrogen*	%	0.23	0.30 - 0.60
C/N Ratio*		12.0	
Anaerobically Mineralisable N/Total N Ratio*	%	2.3	3.0 - 5.0
'Total' Zinc*	mg/kg	94	
'Total' Copper*	mg/kg	22	
'Total' Chromium*	mg/kg	18.8	
'Total' Arsenic*	mg/kg	5.7	
'Total' Lead*	mg/kg	11.3	
'Total' Nickel*	mg/kg	16.3	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.18	
Soil Sample Depth*	mm	0-100	

	K	Ca	Mg	Na
Base Saturation %	K 3.3	Ca 79	Mg 8.2	Na 0.2
MAF Units	K 10	Ca 15	Mg 28	Na < 2

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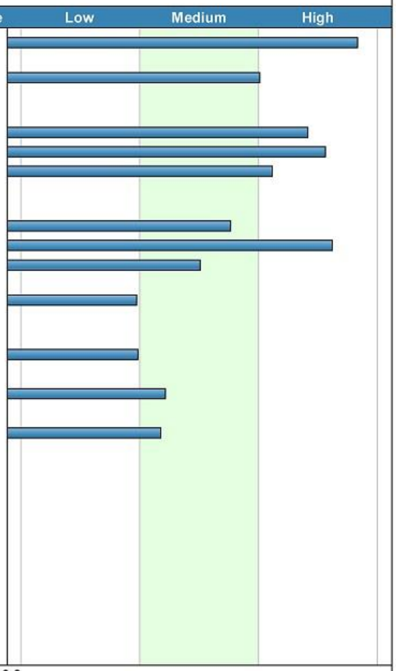
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155784 **Lab Number:** 1486113.9
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	7.0	5.8 - 6.2
Olsen Phosphorus	mg/L	31	20 - 30
Anion Storage Capacity (estimated)*	%	20	
Potassium	me/100g	0.85	0.40 - 0.60
Calcium	me/100g	17.9	4.0 - 10.0
Magnesium	me/100g	1.91	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	22	12 - 25
Total Base Saturation	%	94	50 - 85
Volume Weight	g/mL	0.80	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	147	150 - 250
Anaerobically Mineralisable N*	µg/g	122	
Organic Matter*	%	6.9	7.0 - 17.0
Total Carbon*	%	4.0	
Total Nitrogen*	%	0.36	0.30 - 0.60
C/N Ratio*		11.0	
Anaerobically Mineralisable N/Total N Ratio*	%	3.4	3.0 - 5.0
'Total' Zinc*	mg/kg	74	
'Total' Copper*	mg/kg	20	
'Total' Chromium*	mg/kg	22	
'Total' Arsenic*	mg/kg	5.4	
'Total' Lead*	mg/kg	9.9	
'Total' Nickel*	mg/kg	17.5	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.19	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 3.9 Ca 82	Mg 8.7 Na 0.2
MAF Units		K 14 Ca 18	Mg 35 Na < 2



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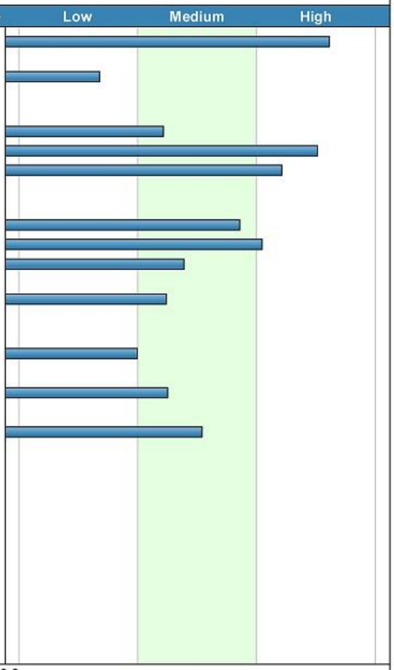
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155796 **Lab Number:** 1486113.10
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.8	5.8 - 6.2
Olsen Phosphorus	mg/L	15	20 - 30
Anion Storage Capacity (estimated)*	%	20	
Potassium	me/100g	0.44	0.40 - 0.60
Calcium	me/100g	17.2	4.0 - 10.0
Magnesium	me/100g	2.18	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	23	12 - 25
Total Base Saturation	%	86	50 - 85
Volume Weight	g/mL	0.76	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	174	150 - 250
Anaerobically Mineralisable N*	µg/g	153	
Organic Matter*	%	7.0	7.0 - 17.0
Total Carbon*	%	4.0	
Total Nitrogen*	%	0.38	0.30 - 0.60
C/N Ratio*		10.7	
Anaerobically Mineralisable N/Total N Ratio*	%	4.1	3.0 - 5.0
'Total' Zinc*	mg/kg	77	
'Total' Copper*	mg/kg	21	
'Total' Chromium*	mg/kg	18.6	
'Total' Arsenic*	mg/kg	5.1	
'Total' Lead*	mg/kg	10.9	
'Total' Nickel*	mg/kg	16.8	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.22	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 1.9 Ca 74	Mg 9.4 Na 0.2
MAF Units		K 7 Ca 16	Mg 37 Na < 2



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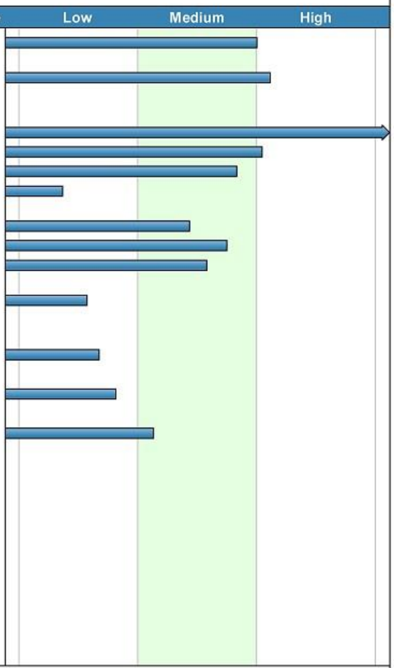
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155808 **Lab Number:** 1486113.11
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.2	5.8 - 6.2
Olsen Phosphorus	mg/L	37	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	1.26	0.40 - 0.60
Calcium	me/100g	10.7	4.0 - 10.0
Magnesium	me/100g	1.50	1.00 - 1.60
Sodium	me/100g	0.07	0.20 - 0.50
CEC	me/100g	18	12 - 25
Total Base Saturation	%	76	50 - 85
Volume Weight	g/mL	0.83	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	107	150 - 250
Anaerobically Mineralisable N*	µg/g	86	
Organic Matter*	%	4.7	7.0 - 17.0
Total Carbon	%	2.7	
Total Nitrogen	%	0.26	0.30 - 0.60
C/N Ratio*		10.4	
Anaerobically Mineralisable N/Total N Ratio*	%	3.3	3.0 - 5.0
'Total' Zinc*	mg/kg	75	
'Total' Copper*	mg/kg	18	
'Total' Chromium*	mg/kg	23	
'Total' Arsenic*	mg/kg	6.2	
'Total' Lead*	mg/kg	17.2	
'Total' Nickel*	mg/kg	18.5	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.17	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 7.1 Ca 60	Mg 8.5 Na 0.4
MAF Units		K 22 Ca 11	Mg 28 Na 3



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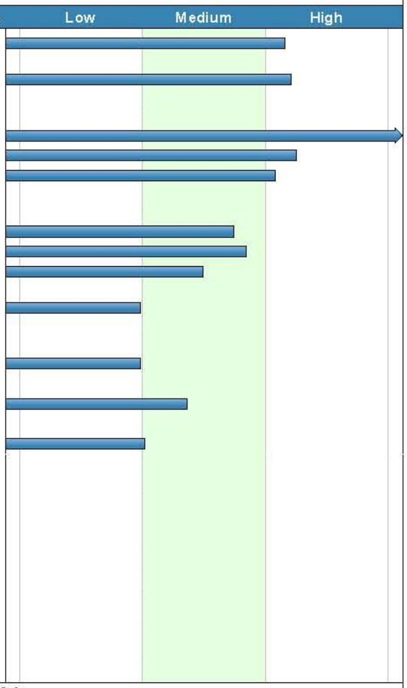
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113	shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015	
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015	
		Quote No:	57142	
		Order No:	4306RRA1	
		Client Reference:	Soil SoE on Sep-2015	
Phone:	03 520 7400	**Submitted By:**	Rachel Rait	

Sample Name: 20155820 **Lab Number:** 1486113.12
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.4	5.8 - 6.2
Olsen Phosphorus	mg/L	43	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	1.79	0.40 - 0.60
Calcium	me/100g	13.6	4.0 - 10.0
Magnesium	me/100g	1.83	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	22	12 - 25
Total Base Saturation	%	80	50 - 85
Volume Weight	g/mL	0.80	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	148	150 - 250
Anaerobically Mineralisable N*	µg/g	124	
Organic Matter*	%	6.9	7.0 - 17.0
Total Carbon*	%	4.0	
Total Nitrogen*	%	0.41	0.30 - 0.60
C/N Ratio*		9.8	
Anaerobically Mineralisable N/Total N Ratio*	%	3.0	3.0 - 5.0
'Total' Zinc*	mg/kg	70	
'Total' Copper*	mg/kg	18	
'Total' Chromium*	mg/kg	26	
'Total' Arsenic*	mg/kg	6.3	
'Total' Lead*	mg/kg	21	
'Total' Nickel*	mg/kg	20	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.19	
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 8.3	Ca 63	Mg 8.4	Na 0.2
MAF Units	K 29	Ca 14	Mg 33	Na < 2

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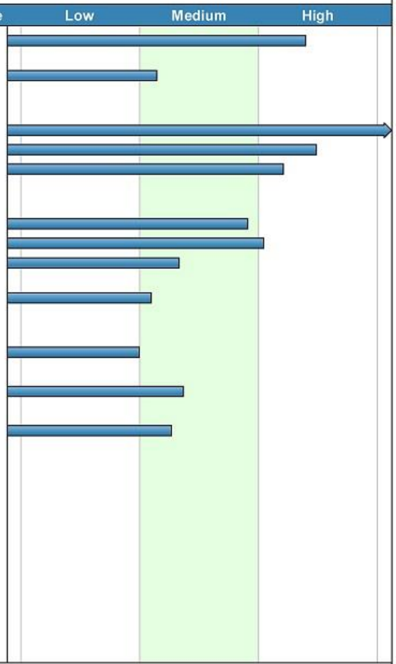
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155832 **Lab Number:** 1486113.13
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.6	5.8 - 6.2
Olsen Phosphorus	mg/L	21	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	1.34	0.40 - 0.60
Calcium	me/100g	16.9	4.0 - 10.0
Magnesium	me/100g	2.17	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	24	12 - 25
Total Base Saturation	%	86	50 - 85
Volume Weight	g/mL	0.73	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	160	150 - 250
Anaerobically Mineralisable N*	µg/g	145	
Organic Matter*	%	7.0	7.0 - 17.0
Total Carbon*	%	4.0	
Total Nitrogen*	%	0.41	0.30 - 0.60
C/N Ratio*		9.8	
Anaerobically Mineralisable N/Total N Ratio*	%	3.5	3.0 - 5.0
'Total' Zinc*	mg/kg	73	
'Total' Copper*	mg/kg	18	
'Total' Chromium*	mg/kg	24	
'Total' Arsenic*	mg/kg	6.6	
'Total' Lead*	mg/kg	16.4	
'Total' Nickel*	mg/kg	19.0	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.16	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 5.6 Ca 71	Mg 9.1 Na 0.2
MAF Units		K 20 Ca 15	Mg 36 Na < 2



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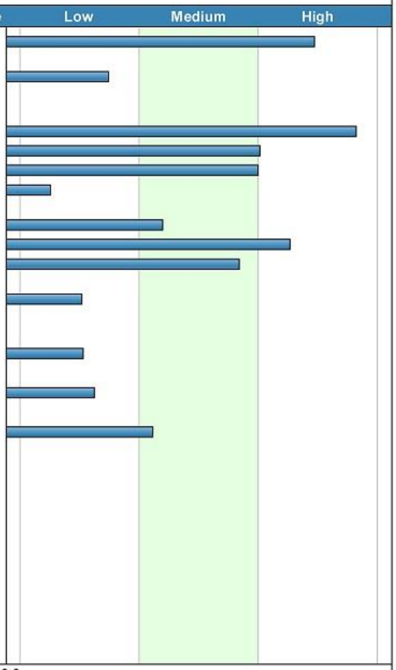
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155844 **Lab Number:** 1486113.14
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.7	5.8 - 6.2
Olsen Phosphorus	mg/L	16	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	1.10	0.40 - 0.60
Calcium	me/100g	10.2	4.0 - 10.0
Magnesium	me/100g	1.61	1.00 - 1.60
Sodium	me/100g	0.05	0.20 - 0.50
CEC	me/100g	15	12 - 25
Total Base Saturation	%	89	50 - 85
Volume Weight	g/mL	0.94	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	102	150 - 250
Anaerobically Mineralisable N*	µg/g	72	
Organic Matter*	%	3.7	7.0 - 17.0
Total Carbon*	%	2.1	
Total Nitrogen*	%	0.22	0.30 - 0.60
C/N Ratio*		9.6	
Anaerobically Mineralisable N/Total N Ratio*	%	3.2	3.0 - 5.0
'Total' Zinc*	mg/kg	69	
'Total' Copper*	mg/kg	21	
'Total' Chromium*	mg/kg	27	
'Total' Arsenic*	mg/kg	5.5	
'Total' Lead*	mg/kg	11.6	
'Total' Nickel*	mg/kg	18.8	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.13	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 7.5 Ca 70	Mg 11.0 Na 0.3
MAF Units		K 21 Ca 12	Mg 34 Na 2



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		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155856 **Lab Number:** 1486113.15
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.6	5.8 - 6.2
Olsen Phosphorus	mg/L	23	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	1.48	0.40 - 0.60
Calcium	me/100g	14.5	4.0 - 10.0
Magnesium	me/100g	2.00	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	20	12 - 25
Total Base Saturation	%	88	50 - 85
Volume Weight	g/mL	0.83	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	152	150 - 250
Anaerobically Mineralisable N*	µg/g	122	
Organic Matter*	%	6.8	7.0 - 17.0
Total Carbon*	%	3.9	
Total Nitrogen*	%	0.40	0.30 - 0.60
C/N Ratio*		9.9	
Anaerobically Mineralisable N/Total N Ratio*	%	3.1	3.0 - 5.0
'Total' Zinc*	mg/kg	59	
'Total' Copper*	mg/kg	20	
'Total' Chromium*	mg/kg	26	
'Total' Arsenic*	mg/kg	5.2	
'Total' Lead*	mg/kg	11.6	
'Total' Nickel*	mg/kg	21	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.16	
Soil Sample Depth*	mm	0-100	

	K	Ca	Mg	Na
Base Saturation %	K 7.3	Ca 71	Mg 9.8	Na 0.2
MAF Units	K 25	Ca 15	Mg 37	Na < 2

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
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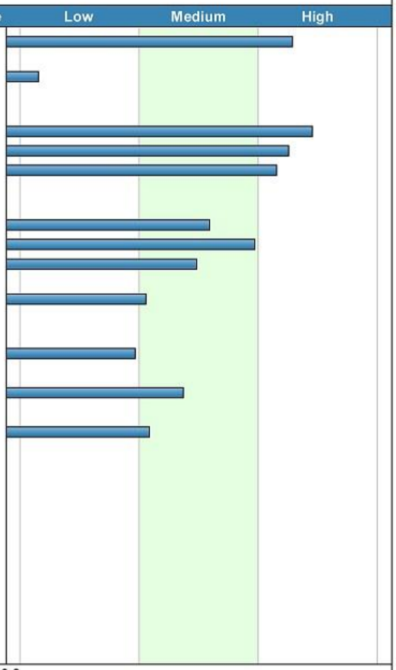
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155868 **Lab Number:** 1486113.16
Sample Type: SOIL Mixed Pasture (S1)

Analysis	Unit	Level Found	Medium Range
pH	pH Units	6.5	5.8 - 6.2
Olsen Phosphorus	mg/L	7	20 - 30
Anion Storage Capacity (estimated)*	%	< 15	
Potassium	me/100g	0.87	0.40 - 0.60
Calcium	me/100g	13.6	4.0 - 10.0
Magnesium	me/100g	2.02	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	20	12 - 25
Total Base Saturation	%	84	50 - 85
Volume Weight	g/mL	0.79	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	156	150 - 250
Anaerobically Mineralisable N*	µg/g	131	
Organic Matter*	%	6.8	7.0 - 17.0
Total Carbon*	%	3.9	
Total Nitrogen*	%	0.41	0.30 - 0.60
C/N Ratio*		9.5	
Anaerobically Mineralisable N/Total N Ratio*	%	3.2	3.0 - 5.0
'Total' Zinc*	mg/kg	59	
'Total' Copper*	mg/kg	22	
'Total' Chromium*	mg/kg	22	
'Total' Arsenic*	mg/kg	5.3	
'Total' Lead*	mg/kg	11.6	
'Total' Nickel*	mg/kg	17.0	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.16	
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 4.4	Ca 69	Mg 10.2	Na 0.2
MAF Units	K 14	Ca 14	Mg 36	Na < 2

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Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155880 **Lab Number:** 1486113.17
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	5.9	5.8 - 6.2			
Olsen Phosphorus	mg/L	28	20 - 30			
Anion Storage Capacity (estimated)*	%	26				
Potassium	me/100g	0.42	0.40 - 0.60			
Calcium	me/100g	8.3	4.0 - 10.0			
Magnesium	me/100g	0.70	1.00 - 1.60			
Sodium	me/100g	0.11	0.20 - 0.50			
CEC	me/100g	15	12 - 25			
Total Base Saturation	%	62	50 - 85			
Volume Weight	g/mL	0.93	0.60 - 1.00			
Available Nitrogen (15cm Depth)*	kg/ha	118	150 - 250			
Anaerobically Mineralisable N*	µg/g	84				
Organic Matter*	%	4.9	7.0 - 17.0			
Total Carbon*	%	2.8				
Total Nitrogen*	%	0.31	0.30 - 0.60			
C/N Ratio*		9.1				
Anaerobically Mineralisable N/Total N Ratio*	%	2.7	3.0 - 5.0			
'Total' Zinc*	mg/kg	59				
'Total' Copper*	mg/kg	6				
'Total' Chromium*	mg/kg	24				
'Total' Arsenic*	mg/kg	2.7				
'Total' Lead*	mg/kg	8.4				
'Total' Nickel*	mg/kg	16.1				
'Total' Mercury*	mg/kg	< 0.11				
'Total' Cadmium*	mg/kg	0.15				
Soil Sample Depth*	mm	0-100				
Base Saturation %		K 2.7 Ca 54	Mg 4.5 Na 0.7			
MAF Units		K 8 Ca 10	Mg 15 Na 5			

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ANALYSIS REPORT

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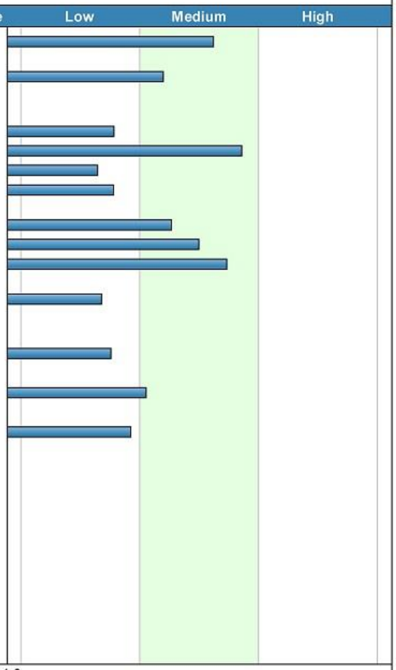
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155939 **Lab Number:** 1486113.18
Sample Type: SOIL Mixed Pasture (S1)

Analysis	Unit	Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.2
Olsen Phosphorus	mg/L	22	20 - 30
Anion Storage Capacity (estimated)*	%	24	
Potassium	me/100g	0.35	0.40 - 0.60
Calcium	me/100g	9.2	4.0 - 10.0
Magnesium	me/100g	0.75	1.00 - 1.60
Sodium	me/100g	0.16	0.20 - 0.50
CEC	me/100g	15	12 - 25
Total Base Saturation	%	67	50 - 85
Volume Weight	g/mL	0.89	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	118	150 - 250
Anaerobically Mineralisable N*	µg/g	88	
Organic Matter*	%	5.3	7.0 - 17.0
Total Carbon*	%	3.1	
Total Nitrogen*	%	0.32	0.30 - 0.60
C/N Ratio*		9.8	
Anaerobically Mineralisable N/Total N Ratio*	%	2.8	3.0 - 5.0
'Total' Zinc*	mg/kg	61	
'Total' Copper*	mg/kg	7	
'Total' Chromium*	mg/kg	15.3	
'Total' Arsenic*	mg/kg	3.1	
'Total' Lead*	mg/kg	9.1	
'Total' Nickel*	mg/kg	12.1	
'Total' Mercury*	mg/kg	< 0.10	
'Total' Cadmium*	mg/kg	0.15	
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 2.2	Ca 59	Mg 4.9	Na 1.0
MAF Units	K 6	Ca 10	Mg 15	Na 6

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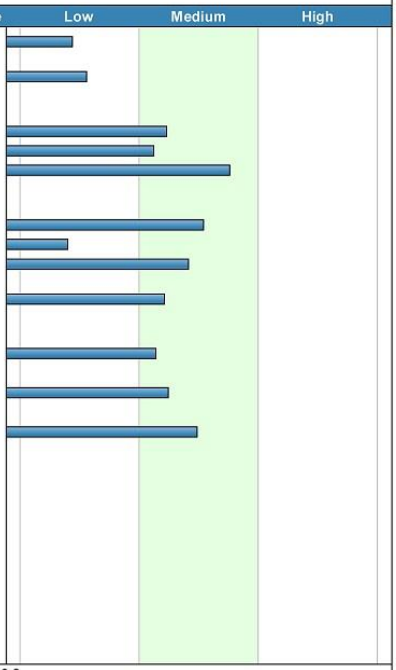
Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155951 **Lab Number:** 1486113.19
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.3	5.8 - 6.2
Olsen Phosphorus	mg/L	13	20 - 30
Anion Storage Capacity (estimated)*	%	35	
Potassium	me/100g	0.45	0.40 - 0.60
Calcium	me/100g	4.7	4.0 - 10.0
Magnesium	me/100g	1.46	1.00 - 1.60
Sodium	me/100g	< 0.05	0.20 - 0.50
CEC	me/100g	19	12 - 25
Total Base Saturation	%	35	50 - 85
Volume Weight	g/mL	0.77	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	171	150 - 250
Anaerobically Mineralisable N*	µg/g	149	
Organic Matter*	%	8.4	7.0 - 17.0
Total Carbon*	%	4.9	
Total Nitrogen*	%	0.37	0.30 - 0.60
C/N Ratio*		13.0	
Anaerobically Mineralisable N/Total N Ratio*	%	4.0	3.0 - 5.0
'Total' Zinc*	mg/kg	71	
'Total' Copper*	mg/kg	18	
'Total' Chromium*	mg/kg	21	
'Total' Arsenic*	mg/kg	5.7	
'Total' Lead*	mg/kg	9.8	
'Total' Nickel*	mg/kg	21	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.15	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 2.3 Ca 25	Mg 7.6 Na 0.2
MAF Units		K 7 Ca 5	Mg 25 Na < 2



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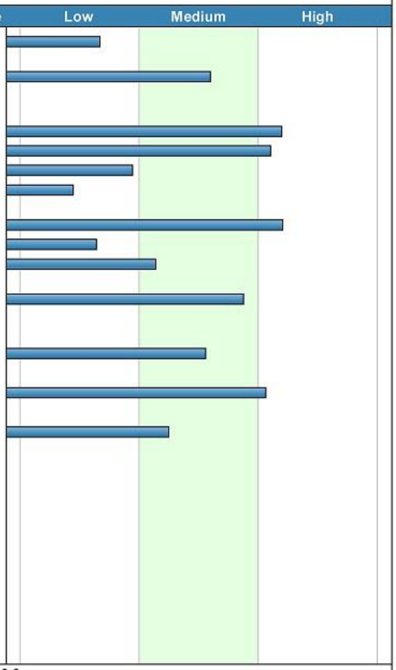
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155963 **Lab Number:** 1486113.20
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.5	5.8 - 6.2
Olsen Phosphorus	mg/L	26	20 - 30
Anion Storage Capacity (estimated)*	%	63	
Potassium	me/100g	0.72	0.40 - 0.60
Calcium	me/100g	11.5	4.0 - 10.0
Magnesium	me/100g	0.96	1.00 - 1.60
Sodium	me/100g	0.09	0.20 - 0.50
CEC	me/100g	32	12 - 25
Total Base Saturation	%	41	50 - 85
Volume Weight	g/mL	0.66	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	238	150 - 250
Anaerobically Mineralisable N*	µg/g	242	
Organic Matter*	%	12.6	7.0 - 17.0
Total Carbon*	%	7.3	
Total Nitrogen*	%	0.69	0.30 - 0.60
C/N Ratio*		10.6	
Anaerobically Mineralisable N/Total N Ratio*	%	3.5	3.0 - 5.0
'Total' Zinc*	mg/kg	65	
'Total' Copper*	mg/kg	15	
'Total' Chromium*	mg/kg	26	
'Total' Arsenic*	mg/kg	4.5	
'Total' Lead*	mg/kg	13.8	
'Total' Nickel*	mg/kg	10.1	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.67	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 2.2 Ca 36	Mg 3.0 Na 0.3
MAF Units		K 10 Ca 9	Mg 14 Na 3



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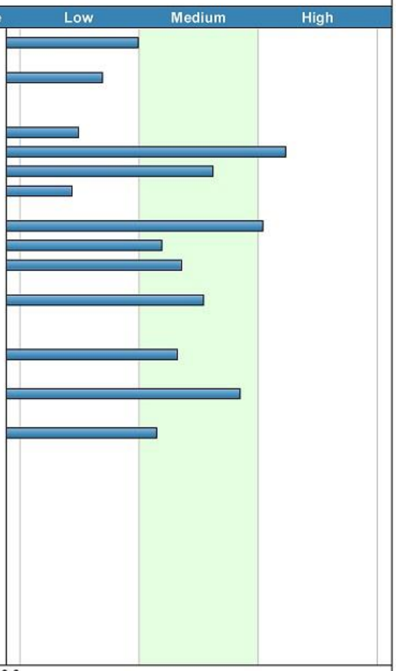
ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Name: 20155975 **Lab Number:** 1486113.21
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.2
Olsen Phosphorus	mg/L	15	20 - 30
Anion Storage Capacity (estimated)*	%	48	
Potassium	me/100g	0.27	0.40 - 0.60
Calcium	me/100g	13.2	4.0 - 10.0
Magnesium	me/100g	1.37	1.00 - 1.60
Sodium	me/100g	0.09	0.20 - 0.50
CEC	me/100g	26	12 - 25
Total Base Saturation	%	57	50 - 85
Volume Weight	g/mL	0.74	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	204	150 - 250
Anaerobically Mineralisable N*	µg/g	183	
Organic Matter*	%	10.2	7.0 - 17.0
Total Carbon*	%	5.9	
Total Nitrogen*	%	0.56	0.30 - 0.60
C/N Ratio*		10.7	
Anaerobically Mineralisable N/Total N Ratio*	%	3.3	3.0 - 5.0
'Total' Zinc*	mg/kg	63	
'Total' Copper*	mg/kg	15	
'Total' Chromium*	mg/kg	31	
'Total' Arsenic*	mg/kg	5.1	
'Total' Lead*	mg/kg	13.1	
'Total' Nickel*	mg/kg	14.1	
'Total' Mercury*	mg/kg	< 0.11	
'Total' Cadmium*	mg/kg	0.43	
Soil Sample Depth*	mm	0-100	
Base Saturation %		K 1.0 Ca 50	Mg 5.2 Na 0.3
MAF Units		K 4 Ca 12	Mg 23 Na 3



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		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Analyst's Comments

Samples 1-21 Comment:
The medium range guidelines shown in the histogram report relate to sampling protocols as per Hill Laboratories' crop guides and are based on reference values where these are published. Results for samples collected to different depths than those described in the crop guide should be interpreted with caution.
For pastoral soils, the medium ranges are specific for a 75mm sample depth, but if a 150mm sampling depth is used the nutrient levels measured may appear low against these ranges, as nutrients are typically more concentrated in the top of the soil profile. These soil profile differences are altered upon cultivation or contouring.

Samples 1-21 Comment:
While soil Mg MAF levels of 8-10 are sufficient for pasture production, soil levels of 25-30 are required to ensure adequate Mg content in pasture for animal health (greater than 0.22%).

Samples 1-21 Comment:
The Available Nitrogen (kg/ha) test above assumes the sample is taken to a 15 cm depth. If the depth is 7.5 cm, then the result reported above should be divided by two.
To calculate Available Nitrogen (as kgN/ha) for other sample depths use the reported Anaerobic Mineralisable Nitrogen (AMN) result in the following equation:
AN (kg/ha) = AMN (µg/g) x VW (g/ml) x sample depth (cm) x 0.1
Note that the AN and AMN results reported include the readily available Mineral N (NH4-N and NO3-N) fraction, which is typically quite low.

Samples 1-21 Comment:
Anion Storage Capacity (also known as Phosphate Retention) is an inherent property of the soil type and does not change. Phosphorus and sulphur fertiliser recommendations should take this value into account.

Sample 2 Comment:
The low CEC level found in this soil indicates that it can only retain cation nutrients (potassium, calcium, magnesium and sodium) at low levels. The normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Sample Registration*	Samples were registered according to instructions received.	-	1-21
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-21
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH.	0.1 pH Units	1-21
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry.	1 mg/L	1-21
Anion Storage Capacity (estimated)*	Equilibration with 0.02M potassium phosphate solution followed by ICP-OES. The standard sulphur extract is utilised, where the extraction conditions differ from the reference method. An in-house conversion formula is used to convert this result to the reference method equivalent.	15 %	1-21
Potassium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-21
Calcium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-21

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		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Magnesium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-21
Sodium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	2 MAF units	1-21
Available Nitrogen*	Determined by NIR, calibration based on Available N by Anaerobic incubation followed by extraction using 2M KCl followed by Berthelot colorimetry. (Calculation based on 15cm depth sample).	1 mg/L	1-21
Anaerobically Mineralisable N*	As for Available Nitrogen but reported as µg/g.	5 µg/g	1-21
Organic Matter*	Organic Matter is 1.72 x Total Carbon.	0.2 %	1-21
Total Carbon	Dumas combustion.	0.1 %	11
Total Nitrogen	Dumas combustion.	0.04 %	11
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	1-10, 12-21
Total Nitrogen*	Determined by NIR, calibration based on Total N by Dumas combustion.	0.04 %	1-10, 12-21
'Total' Zinc*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-OES. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	4 mg/kg	1-21
'Total' Copper*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-OES. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	4 mg/kg	1-21
'Total' Chromium*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-MS. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	0.2 mg/kg	1-21
'Total' Arsenic*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-MS. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	0.2 mg/kg	1-21
'Total' Lead*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-MS. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	0.04 mg/kg	1-21
'Total' Nickel*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-MS. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	0.2 mg/kg	1-21

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ANALYSIS REPORT

Client:	Marlborough District Council	**Lab No:**	1486113 shpv1
Address:	PO Box 443	**Date Registered:**	08-Oct-2015
	BLENHEIM 7240	**Date Reported:**	15-Oct-2015
		Quote No:	57142
		Order No:	4306RRA1
		Client Reference:	Soil SoE on Sep-2015
Phone:	03 520 7400	**Submitted By:**	Rachel Rait

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
'Total' Mercury*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-MS. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	0.10 mg/kg	1-21
'Total' Cadmium*	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-MS. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements.	0.02 mg/kg	1-21
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.01 me/100g	1-21
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.5 me/100g	1-21
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.04 me/100g	1-21
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.05 me/100g	1-21
Potassium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-21
Calcium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 %BS	1-21
Magnesium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.2 %BS	1-21
Sodium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-21
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity. May be overestimated if soil contains high levels of soluble salts or carbonates.	2 me/100g	1-21
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-21
Volume Weight	The weight/volume ratio of dried, ground soil.	0.01 g/mL	1-21

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

W.M.Homewood.

Wendy Homewood
Operations Support - Agriculture Division

T- test results from comparing changes in soil indicators since 2010

Cropping sites

Paired T-Test and CI: pH, pH_1

```
Paired T for pH - pH_1

             N   Mean  StDev  SE Mean
pH           6  6.250  0.351    0.143
pH_1         6  5.983  0.133    0.054
Difference   6  0.267  0.339    0.138


95% CI for mean difference: (-0.089, 0.622)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.93  P-Value = 0.112
```

Paired T-Test and CI: OP, OP_1

```
Paired T for OP - OP_1

             N   Mean  StDev  SE Mean
OP           6  31.00  15.34     6.26
OP_1         6  31.50   8.04     3.28
Difference   6  -0.50   9.75     3.98


95% CI for mean difference: (-10.73, 9.73)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.13  P-Value = 0.905
```

Paired T-Test and CI: AMN, AMN_1

```
Paired T for AMN - AMN_1

             N   Mean  StDev  SE Mean
AMN          6  56.17   8.82     3.60
AMN_1        6  56.17  23.74     9.69
Difference   6    0.0   26.8     10.9


95% CI for mean difference: (-28.1, 28.1)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 0.00  P-Value = 1.000
```

Paired T-Test and CI: Total C, Total C_1

```
Paired T for Total C - Total C_1

             N   Mean  StDev  SE Mean
Total C      6  2.633  0.493    0.201
Total C_1    6  2.283  0.649    0.265
Difference   6  0.350  0.657    0.268


95% CI for mean difference: (-0.339, 1.039)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.31  P-Value = 0.248
```

Paired T-Test and CI: Total N, Total N_1

```
Paired T for Total N - Total N_1

             N    Mean   StDev  SE Mean
Total N      6  0.2833  0.0509   0.0208
Total N_1    6  0.2450  0.0647   0.0264
Difference   6  0.0383  0.0671   0.0274


95% CI for mean difference: (-0.0320, 0.1087)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.40  P-Value = 0.220
```

Paired T-Test and CI: BD, BD_1

```
Paired T for BD - BD_1

             N    Mean   StDev  SE Mean
BD           6  1.4550  0.1035   0.0422
BD_1         6  1.4264  0.0680   0.0278
Difference   6  0.0286  0.0706   0.0288


95% CI for mean difference: (-0.0454, 0.1027)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 0.99  P-Value = 0.366
```

Paired T-Test and CI: Macro -10, Macro -10_1

```
Paired T for Macro -10 - Macro -10_1

              N   Mean  StDev  SE Mean
Macro -10     6   7.23   5.22     2.13
Macro -10_1   6   9.07   2.47     1.01
Difference    6  -1.83   5.15     2.10


95% CI for mean difference: (-7.24, 3.58)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.87  P-Value = 0.423
```

Paired T-Test and CI: Cd, Cd_1

```
Paired T for Cd - Cd_1

             N     Mean    StDev  SE Mean
Cd           6   0.1533   0.0378   0.0154
Cd_1         6   0.1333   0.0266   0.0109
Difference   6  0.02000  0.02191  0.00894


95% CI for mean difference: (-0.00299, 0.04299)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 2.24  P-Value = 0.076
```

Paired T-Test and CI: Agg Stab, Agg Stab_1

```
Paired T for Agg Stab - Agg Stab_1

            N    Mean  StDev  SE Mean
Agg Stab    5   0.448  0.078    0.035
Agg Stab_1  5   1.168  0.301    0.134
Difference  5  -0.720  0.343    0.153


95% CI for mean difference: (-1.145, -0.295)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -4.70  P-Value = 0.009
```

Dairy sites

Paired T-Test and CI: pH, pH_1

```
Paired T for pH - pH_1

            N    Mean   StDev  SE Mean
pH          2   5.700   0.141    0.100
pH_1        2   5.650   0.212    0.150
Difference  2  0.0500  0.0707   0.0500


95% CI for mean difference: (-0.5853, 0.6853)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.00  P-Value = 0.500
```

Paired T-Test and CI: OP, OP_1

```
Paired T for OP - OP_1

            N   Mean  StDev  SE Mean
OP          2  29.50  12.02     8.50
OP_1        2  20.50   7.78     5.50
Difference  2   9.00   4.24     3.00


95% CI for mean difference: (-29.12, 47.12)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 3.00  P-Value = 0.205
```

Paired T-Test and CI: AMN, AMN_1

```
Paired T for AMN - AMN_1

            N   Mean  StDev  SE Mean
AMN         2  193.0   12.7      9.0
AMN_1       2  212.5   41.7     29.5
Difference  2  -19.5   29.0     20.5


95% CI for mean difference: (-280.0, 241.0)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.95  P-Value = 0.516
```

Paired T-Test and CI: Total C, Total C_1

```
Paired T for Total C - Total C_1

            N   Mean  StDev  SE Mean
Total C     2  6.900  1.273    0.900
Total C_1   2  6.600  0.990    0.700
Difference  2  0.300  0.283    0.200


95% CI for mean difference: (-2.241, 2.841)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.50  P-Value = 0.374
```

Paired T-Test and CI: Total N, Total N_1

```
Paired T for Total N - Total N_1

            N      Mean    StDev  SE Mean
Total N     2    0.6100   0.0849   0.0600
Total N_1   2    0.6250   0.0919   0.0650
Difference  2  -0.01500  0.00707  0.00500


95% CI for mean difference: (-0.07853, 0.04853)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -3.00  P-Value = 0.205
```

Paired T-Test and CI: BD, BD_1

```
Paired T for BD - BD_1

            N     Mean   StDev  SE Mean
BD          2   0.8750  0.0212   0.0150
BD_1        2   0.9292  0.1365   0.0965
Difference  2  -0.0542  0.1153   0.0815


95% CI for mean difference: (-1.0897, 0.9814)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.66  P-Value = 0.627
```

Paired T-Test and CI: Macro -10, Macro -10_1

```
Paired T for Macro -10 - Macro -10_1

             N   Mean  StDev  SE Mean
Macro -10    2  10.80   0.28     0.20
Macro -10_1  2   7.45   6.86     4.85
Difference   2   3.35   6.58     4.65


95% CI for mean difference: (-55.73, 62.43)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 0.72  P-Value = 0.603
```

Paired T-Test and CI: Cd, Cd_1

```
Paired T for Cd - Cd_1

             N   Mean  StDev  SE Mean
Cd           2  0.775  0.346    0.245
Cd_1         2  0.550  0.170    0.120
Difference   2  0.225  0.177    0.125


95% CI for mean difference: (-1.363, 1.813)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.80  P-Value = 0.323
```

Vineyard – vine sites

Paired T-Test and CI: pH, pH_1

```
Paired T for pH - pH_1

             N   Mean  StDev  SE Mean
pH           4  6.550  0.191    0.096
pH_1         4  6.525  0.538    0.269
Difference   4  0.025  0.457    0.229


95% CI for mean difference: (-0.703, 0.753)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 0.11  P-Value = 0.920
```

Paired T-Test and CI: OP, OP_1

```
Paired T for OP - OP_1

             N   Mean  StDev  SE Mean
OP           4  21.75  10.53     5.27
OP_1         4  25.25   8.85     4.42
Difference   4  -3.50   2.08     1.04


95% CI for mean difference: (-6.81, -0.19)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -3.36  P-Value = 0.044
```

Paired T-Test and CI: AMN, AMN_1

```
Paired T for AMN - AMN_1

             N  Mean  StDev  SE Mean
AMN          4  72.5   30.9     15.5
AMN_1        4  71.5   13.7      6.9
Difference   4   1.0   43.1     21.5


95% CI for mean difference: (-67.6, 69.6)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 0.05  P-Value = 0.966
```

Paired T-Test and CI: Total C, Total C_1

```
Paired T for Total C - Total C_1

             N     Mean   StDev  SE Mean
Total C      4    2.725   0.574    0.287
Total C_1    4    2.750   0.574    0.287
Difference   4  -0.0250  0.0957   0.0479


95% CI for mean difference: (-0.1773, 0.1273)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.52  P-Value = 0.638
```

Paired T-Test and CI: Total N, Total N_1

```
Paired T for Total N - Total N_1

             N    Mean   StDev  SE Mean
Total N      4  0.2850  0.0580   0.0290
Total N_1    4  0.2525  0.0359   0.0180
Difference   4  0.0325  0.0287   0.0144


95% CI for mean difference: (-0.0132, 0.0782)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 2.26  P-Value = 0.109
```

Paired T-Test and CI: BD, BD_1

```
Paired T for BD - BD_1

             N    Mean   StDev  SE Mean
BD           4  1.3225  0.0900   0.0450
BD_1         4  1.2973  0.0277   0.0139
Difference   4  0.0252  0.0623   0.0312


95% CI for mean difference: (-0.0740, 0.1244)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 0.81  P-Value = 0.479
```

Paired T-Test and CI: Macro -10, Macro -10_1

```
Paired T for Macro -10 - Macro -10_1

              N    Mean  StDev  SE Mean
Macro -10     4  11.650  1.857    0.929
Macro -10_1   4   9.700  1.581    0.791
Difference    4   1.950  1.338    0.669


95% CI for mean difference: (-0.179, 4.079)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 2.91  P-Value = 0.062
```

Paired T-Test and CI: Cd, Cd_1

```
Paired T for Cd - Cd_1

            N    Mean   StDev  SE Mean
Cd          4  0.1775  0.0512   0.0256
Cd_1        4  0.1525  0.0263   0.0131
Difference  4  0.0250  0.0332   0.0166


95% CI for mean difference: (-0.0278, 0.0778)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.51  P-Value = 0.229
```

Vineyard – wheel sites

Paired T-Test and CI: pH, pH_1

```
Paired T for pH - pH_1

            N   Mean  StDev  SE Mean
pH          4  6.725  0.236    0.118
pH_1        4  6.525  0.377    0.189
Difference  4  0.200  0.258    0.129


95% CI for mean difference: (-0.211, 0.611)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 1.55  P-Value = 0.219
```

Paired T-Test and CI: OP, OP_1

```
Paired T for OP - OP_1

            N   Mean  StDev  SE Mean
OP          4  28.25  14.89     7.44
OP_1        4  29.00  10.58     5.29
Difference  4  -0.75   6.65     3.33


95% CI for mean difference: (-11.33, 9.83)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.23  P-Value = 0.836
```

Paired T-Test and CI: AMN, AMN_1

```
Paired T for AMN - AMN_1

            N   Mean  StDev  SE Mean
AMN         4  104.8   36.1     18.0
AMN_1       4  114.0   17.4      8.7
Difference  4   -9.3   30.5     15.3


95% CI for mean difference: (-57.9, 39.4)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.61  P-Value = 0.587
```

Paired T-Test and CI: Total C, Total C_1

```
Paired T for Total C - Total C_1

             N    Mean  StDev  SE Mean
Total C      4   3.525  0.250    0.125
Total C_1    4   3.875  0.189    0.095
Difference   4  -0.350  0.370    0.185


95% CI for mean difference: (-0.938, 0.238)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -1.89  P-Value = 0.155
```

Paired T-Test and CI: Total N, Total N_1

```
Paired T for Total N - Total N_1

             N     Mean   StDev  SE Mean
Total N      4   0.3600  0.0383   0.0191
Total N_1    4   0.3800  0.0294   0.0147
Difference   4  -0.0200  0.0216   0.0108


95% CI for mean difference: (-0.0544, 0.0144)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -1.85  P-Value = 0.161
```

Paired T-Test and CI: BD, BD_1

```
Paired T for BD - BD_1

             N    Mean   StDev  SE Mean
BD           4  1.4125  0.0780   0.0390
BD_1         4  1.2654  0.1101   0.0551
Difference   4  0.1471  0.0937   0.0468


95% CI for mean difference: (-0.0020, 0.2961)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 3.14  P-Value = 0.052
```

Paired T-Test and CI: Macro -10, Macro -10_1

```
Paired T for Macro -10 - Macro -10_1

               N   Mean  StDev  SE Mean
Macro -10      4   4.00   0.96     0.48
Macro -10_1    4   6.10   5.59     2.80
Difference     4  -2.10   6.14     3.07


95% CI for mean difference: (-11.86, 7.66)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.68  P-Value = 0.543
```

Paired T-Test and CI: Cd, Cd_1

```
Paired T for Cd - Cd_1

            N       Mean    StDev  SE Mean
Cd          4     0.1600   0.0294   0.0147
Cd_1        4     0.1675   0.0287   0.0144
Difference  4  -0.00750  0.01708  0.00854


95% CI for mean difference: (-0.03468, 0.01968)
T-Test of mean difference = 0 (vs ≠ 0): T-Value = -0.88  P-Value = 0.444
```