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Soil Quality in the Marlborough Region 2014

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Report prepared for Marlborough District Council

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1. 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 16 sites that were originally established and sampled in 2009 and analysed for a suite of soil physical, biological and chemical properties – indicators of soil quality.

2. Materials and methods

2.1 Sample site

Soils were sampled from the same sites that were established, sampled and reported in 2009 (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
MDC45a	2009	Pallic	Dashwood	Vineyard	Under the vine
MDC45b					Under the wheel track
MDC45c					Middle of inter-row
MDC46a	2009	Pallic	Sedgemere	Vineyard	Under the vine
MDC46b					Under the wheel track
MDC46c					Middle of inter-row
MDC47	2009	Pallic	Sedgemere	Cropping	
MDC48	2009	Pallic	Sedgemere	Drystock	
MDC49	2009	Brown	Hororata	Exotic forest	
MDC50	2009	Brown	Hororata	Drystock	
MDC51	2009	Brown	Kaituna	Drystock	
MDC52	2009	Brown	Tuamarina	Drystock	
MDC53	2009	Brown	Tuamarina	Exotic forest	
MDC54	2009	Pallic	Weld	Drystock	
MDC55	2009	Pallic	Weld	Exotic forest	
MDC56	2009	Pallic	Warwick	Drystock	
MDC56	2009	Pallic	Wither Hill	Drystock	
MDC58	2009	Pallic	Haldon	Drystock	
MDC59	2009	Pallic	Waihopai Steepland	Exotic forest	
MDC60	2009	Pallic	Waihopai Steepland	Drystock	

*New Zealand Soil Classification

2.2 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).

2.3 Soil quality indicators

A number of different soil properties were measured to assess soil quality. Soil chemical characteristics were assessed by 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

2.4 Soil analysis

2.4.1 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).

2.4.2 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).

2.4.3 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 is measured after sieving (Gradwell, 1972).

It is worth noting that the general definition of macroporosity has recently 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.

2.4.4 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).

2.4.5 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 2009 and 2014, data were tested for normality and a paired t-test performed. All statistical analysis was undertaken using Minitab version 16.22.

3. Results and discussion

3.1 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 C and AMN were within target ranges at all sites sampled, while total N at two sites (10%), bulk density at three (15%) and macroporosity at four sites (20%) were out of the target range. The exception was Olsen P which was outside the target range at 11 sites (55%), although as will be discussed in section 3.7, only one site exceeded the target for Olsen P with the remainder below the target range.

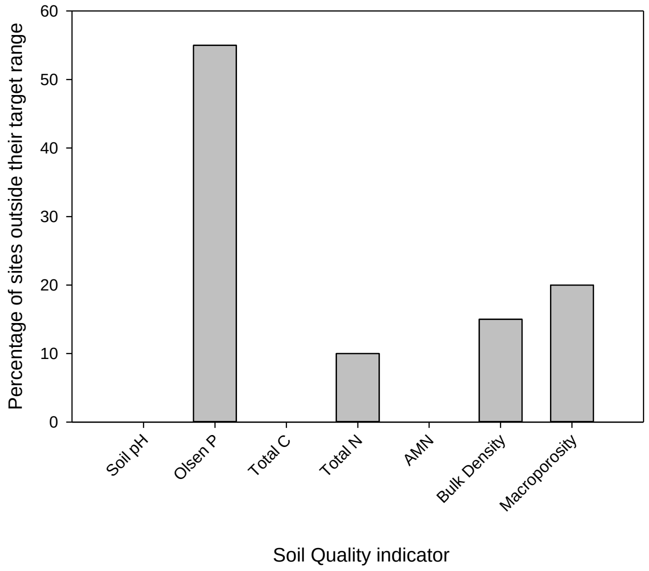

Figure 1. The percentage of sites not meeting their target range for a specific soil quality indicator.

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

3.2 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 thirds of the drystock pasture sites 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.

3.3 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 soil 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, although the cropping site (MDC47) was 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 decrease 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).

3.4 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 but three sites had total N concentrations within the acceptable target range for their respective landuse activity (Table 3). The exceptions were drystock pasture sites, one which marginally exceeded the upper target range (MDC50) and two that were below the range (MDC52). The high value at MDC50 likely reflects the high organic C content in this soil (Table 3) since total N is largely dependent on the amount of soil organic matter. Conversely, the low total N reflects the low organic matter status in those soils.

A high total N can increase the risk that N supply may be in excess of plant demand, and ultimately lead to nitrate N loss from soils. However, there are a number of conditions affecting N loss, one being the carbon:nitrogen ratio discussed below. Suffice to say that with a C:N ratio of around 12 for MDC50, nitrate-N loss isn’t a significant risk. In contrast, low N concentrations in soils can be increased by the application of N fertilisers to soil, or the cultivation of N fixing pasture species. Hence the low values are not of any environmental concern but may impact on optimal pasture production.

3.5 Carbon to Nitrogen ratio

The balance of the amount 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 at drystock pasture sites were between 10:1 up to 12:1, which is typical of long term pasture soils. This reflects the 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). The exception being the four exotic forestry sites which were higher (13 – 16). Exotic forest soils typically have C:N high ratios often >15 but are variable depending on whether they have been planted directly into cleared bush, a prepared site, second or third rotation, scrub, or former pasture.

3.6 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).

Table 3. Soil chemical, physical and biological characteristics of soils sampled in 2014. 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 (-10kPa)	Aggregate Stability	Macroporosity (-5kPa)	C:N ratio
				(mg/L)	(mg/kg)	(%)	(%)	(Mg/m3)	(% v/v)	(mwd)	(% v/v)	
MDC45a	Vineyard	Pallic	6.7	30	128	5.1	0.44	1.2	19.0		16.3	11.5
MDC45b			6.5	35	92	4.1	0.35	1.1	13.3		9.8	11.6
MDC45c			6.4	39	132	5.1	0.54	1.0	11.4		8.7	9.5
MDC46a	Vineyard	Pallic	6.5	**7**	121	2.6	0.22	**1.4**	7.6		5.8	11.9
MDC46b			6.7	**21**	96	3.0	0.26	**1.4**	**4.2**		3.0	11.6
MDC46c			6.5	**16**	107	2.5	0.26	1.3	6.7		5.1	9.5
MDC47	Cropping	Pallic	6.0	**7**	74	2.3	0.23	**1.4**	**5.7**	**0.46**	4.2	9.8
MDC48	Drystock	Pallic	5.7	**10**	127	3.5	0.31	1.1	6.1		3.1	11.5
MDC49	Exotic forest	Brown	4.9	16	104	7.1	0.45	0.8	36.5		31.5	15.7
MDC50	Drystock	Brown	5.6	21	179	8.4	**0.72**	0.8	16.9		11.6	11.7
MDC51	Drystock	Brown	5.8	**8**	107	2.8	**0.25**	1.1	**5.9**		3.5	11.2
MDC52	Drystock	Brown	5.2	**11**	111	2.8	**0.24**	1.2	9.2		6.7	11.5
MDC53	Exotic forest	Brown	5.1	**4**	69	3.2	0.24	1.1	15.6		13.5	12.9
MDC54	Drystock	Pallic	5.5	26	122	4.1	0.37	1.1	15.2		10.3	11.3
MDC55	Exotic forest	Pallic	5.9	17	65	2.6	0.16	1.2	28.6		27.0	15.9
MDC56	Drystock	Pallic	6.0	**12**	120	3.5	0.39	1.3	**6.0**		6.2	9.1
MDC57	Drystock	Pallic	5.5	**50**	130	4.2	0.52	1.1	10.8		6.6	8.1
MDC58	Drystock	Pallic	5.8	17	133	4.1	0.33	1.1	12.9		8.6	12.5
MDC59	Exotic forest	Pallic	5.5	20	83	3.6	0.27	1.0	27.8		23.6	13.6
MDC60	Drystock	Pallic	5.5	**9**	145	4.1	0.37	1.2	10.9		7.3	11.1

3.7 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.

Only one site (MDC57) had an 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, restricted grazing, low rate effluent application to soil, stream fencing, sediment traps, grass buffer strips, constructed wetlands, and application of amendments to sorb P in soil and drainage water (McDowell, 2012). 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 five drystock sites (MDC48; MDC51; MDC52; MDC56; MDC60), the cropping site (MDC47), and one of the exotic forestry sites (MDC53) 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.

3.8 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 the cropping site (MDC47) and the wheel track and vine region of one of the vineyard sites (MDC46) 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 3.3. However, it is also recognised that some Pallic soils like the Sedgemere 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. However, surprisingly there was also a high bulk density in the vine area from this site despite not subject to machinery traffic. Like the cropping site, the soil is a Pallic Sedgemere soil and it may be structurally vulnerable due to slaking. This would be exacerbated by the lack of vegetative cover in the soil under the vine.

3.9 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 four sites met their target for macroporosity (Table 3). The four that did not included two of the drystock sites i.e. MDC51 MDC56, the cropping site i.e. MDC47 and the wheel track area of one vineyard site, i.e. MDC46b.

Low macroporosity at some drystock pasture sites has been noted previously in Marlborough (Gray, 2013) 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 drystock sites, low macroporosity on cropping sites has also been widely recognised across NZ (Sorensen, 2010). At the one cropping site sampled the low macroporosity as discussed in section 3.3 was likely related to the depleted organic C in this soil, along with the high slaking potential and the use of machinery, especially when soil conditions are too wet for heavy equipment - which has compressed the larger pores.

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.

3.10 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 site MDC47 (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.

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). Pallic soils are usually regarded as unsuitable for continuous cropping to due to their potential for soil structural collapse.

3.11 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 in soils and their accumulation can also have a negative impact on soil, plant and animal health, and in some cases there is potential for them 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.

Table 4. Trace element concentrations (mg kg^{-1}) in soils sampled in the Marlborough Region 2014.

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})
MDC45a	Vineyard	78	8	26	4	14	15	0.03	0.20
MDC45b		75	7	23	4	12	13	0.03	0.20
MDC45c		77	9	25	4	12	15	0.03	0.19
MDC46a	Vineyard	46	5	19	2	8	10	0.03	0.15
MDC46b		52	6	18	4	8	10	0.03	0.17
MDC46c		50	5	17	2	8	10	0.03	0.15
MDC47	Cropping	42	< 4	15	2	7	9	0.04	0.14
MDC48	Drystock	43	4	20	2	7	11	0.03	0.12
MDC49	Exotic forest	46	< 4	22	3	34	12	0.05	0.03
MDC50	Drystock	43	7	26	3	12	14	0.04	0.17
MDC51	Drystock	43	11	41	3	9	20	0.02	0.24
MDC52	Drystock	15	5	36	2	6	18	0.02	0.06
MDC53	Exotic forest	47	16	57	5	12	33	0.02	0.03
MDC54	Drystock	67	11	14	5	15	10	0.02	0.08
MDC55	Exotic forest	67	10	16	4	17	14	0.02	0.07
MDC56	Drystock	60	8	18	3	9	13	0.03	0.18
MDC57	Drystock	52	9	14	4	8	10	0.02	0.22
MDC58	Drystock	61	10	15	4	10	10	0.03	0.15
MDC59	Exotic forest	35	7	15	1	8	11	0.02	0.11
MDC60	Drystock	38	8	18	2	8	13	0.02	0.14

3.12 Changes since 2009

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 2009, 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 2009 and again in 2014 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 2009, comparisons were made to soils sampled from this zone in 2014.

There were no statistically significant changes in soil indicators between sampling dates.

Table 5. Mean changes in soil quality indicators for sites sampled in 2009 and 2014. * significant level of change (*$p < 0.05$).

Site code	Landuse	pH	Olsen P	AMN	Total C	Total N	Bulk density	Macroporosity	Cd
			mg/L	(mg kg^{-1})	(%)	(%)	Mg/m3	-10kPa (%v/v)	(mg kg^{-1})
MDC48	Drystock Pasture	0.1	-5.0	-37	-0.1	-0.06	0.0	0.5	0.02
MDC50	Drystock Pasture	0.5	-2.0	20	0.7	0.04	-0.1	1.4	0.07
MDC51	Drystock Pasture	-0.2	-1.0	-43	-0.6	-0.11	0.0	-2.1	0.03
MDC52	Drystock Pasture	-0.2	0.0	51	-0.3	-0.01	0.0	4.1	-0.04
MDC54	Drystock Pasture	0.3	6.0	-32	0.2	-0.04	0.0	2.4	-0.02
MDC56	Drystock Pasture	0.1	-13.0	-86	0.1	0.00	0.0	-2.4	-0.03
MDC57	Drystock Pasture	0.2	36.0	-57	0.0	0.10	-0.1	-1.3	0.12
MDC58	Drystock Pasture	0.2	6.0	-75	-0.9	-0.15	-0.1	0.8	0.04
MDC60	Drystock Pasture	0.2	-2.0	-40	-0.3	-0.03	0.1	-3.1	0.02
	Mean	0.1	2.8	-33	-0.1	-0.03	0.0	0.0	0.02
MDC49	Exotic forest - pinus radiata	0.0	5.0	16.0	-0.3	-0.08	0.0	7.1	-0.07
MDC53	Exotic forest - pinus radiata	-0.1	-3.0	-15.0	-1.0	-0.06	0.0	-5.3	-0.07
MDC55	Exotic forest - pinus radiata	-0.1	5.0	9.0	0.0	-0.09	-0.2	9.4	-0.03
MDC59	Exotic forest - pinus radiata	0.1	2.0	-24.0	-0.4	-0.07	-0.1	1.7	0.01
	Mean	-0.03	2.3	-3.5	-0.4	-0.08	-0.1	3.2	-0.04
MDC45	Vineyard	-0.5	18.0	-31.0	0.3	0.04	0.0	-3.5	0.07
MDC46	Vineyard	-0.5	1.0	-6.0	-0.4	-0.03	0.0	0.9	-0.01
								-1.3	
	Mean	-0.5	9.5	-19	-0.1	0.01	0.0		0.03
MDC47	Cropping	0.4	-16	-42.0	-0.2	-0.05	0.1	0.2	0.03

4. 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.

- A high Olsen P value was found at one of the drystock pasture 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. 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.

- Two of the drystock pasture sites showed signs of soil compaction i.e. low macroporosity. 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. 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.

5. 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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7. 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/m3 or Mg/m3)

	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

Macroporosity target ranges (% @ -10 kPa)

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

Total carbon target ranges (% w/w)

	Very	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**

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					

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

Soil pH target ranges

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

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

Soil moisture release data 2014 – Landcare Research

Marlborough District Council Soil Quality Monitoring 2014/15
Moisture Release Results
Job: **682208-0075**
December 2014

Lab Number	Client ID	Transect Position	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)
HP6148a*	MDC 59	15 m	1551	23.0	0.89	2.61	65.8	26.5	31.7	39.3	34.1	22.4	9.9	11.7	24.1
HP6148b	MDC 59	30 m	1718	25.9	0.96	2.63	63.4	22.9	27.4	40.5	36.0	28.3	11.5	7.8	24.6
HP6148c*	MDC 59	45 m	1167	27.6	1.02	2.63	61.2	21.5	24.2	39.6	36.9	29.8	12.3	7.2	24.7
HP6149a	MDC 48	15 m	1397	52.6	1.05	2.57	59.0	4.5	7.7	54.5	51.3	39.7	15.0	11.6	36.3
HP6149b	MDC 48	30 m	1022	45.4	1.15	2.56	55.0	2.3	5.4	52.7	49.6	38.6	15.6	11.0	34.0
HP6149c	MDC 48	45 m	1352	44.5	1.18	2.55	53.8	2.5	5.1	51.3	48.7	38.8	15.6	9.9	33.1
HP6150a	MDC 47	15 m	1014	29.1	1.40	2.59	46.1	2.3	3.7	43.7	42.4	36.6	15.1	5.8	27.3
HP6150b	MDC 47	30 m	1163	25.4	1.39	2.60	46.4	6.2	8.0	40.2	38.4	32.8	15.1	5.6	23.3
HP6150c	MDC 47	45 m	1566	25.1	1.44	2.60	44.5	4.0	5.5	40.5	39.0	33.8	15.7	5.2	23.3
HP6151a	MDC 56	15 m	1099	31.9	1.26	2.56	50.7	1.1	2.9	49.6	47.8	39.8	16.0	8.0	31.7
HP6151b	MDC 56	30 m	1317	32.3	1.30	2.57	49.5	<1	2.0	48.9	47.5	39.8	17.5	7.7	30.0
HP6151c	MDC 56	45 m	1321	24.3	1.18	2.58	54.2	11.2	13.0	42.9	41.2	34.6	15.8	6.7	25.4
HP6152a	MDC 57	15 m	1533	22.6	1.12	2.51	55.5	8.1	12.3	47.4	43.2	34.2	16.4	9.0	26.8
HP6152b	MDC 57	30 m	1581	23.6	1.10	2.45	55.3	2.2	6.8	53.0	48.5	38.6	15.7	9.9	32.9
HP6152c	MDC 57	45 m	1029	22.0	1.11	2.50	55.8	9.6	13.3	46.2	42.5	33.3	17.4	9.2	25.2
HP6153a*	MDC 58	15 m	1654	52.2	0.77	2.52	69.4	17.2	23.0	52.2	46.4	36.5	8.3	9.9	38.1
HP6153b*	MDC 58	30 m	1075	36.0	1.24	2.58	51.8	2.2	5.4	49.6	46.5	35.9	13.3	10.6	33.2
HP6153c*	MDC 58	45 m	1239	36.3	1.19	2.60	54.1	6.5	10.2	47.7	44.0	34.1	14.3	9.9	29.6
HP6154a	MDC 60 20142944	15 m	1208	36.0	1.21	2.61	53.7	6.0	9.1	47.7	44.6	36.4	14.9	8.3	29.8
HP6154b	MDC 60 20142944	30 m	1016	34.6	1.19	2.60	54.2	3.2	7.6	51.0	46.6	33.8	15.0	12.8	31.5
HP6154c	MDC 60 20142944	45 m	1282	28.2	1.18	2.62	54.8	12.6	15.9	42.1	38.9	30.7	15.6	8.2	23.3
HP6155a	MDC 46_vine 201434	15 m	1596	21.6	1.48	2.62	43.6	6.4	8.2	37.2	35.4	31.4	18.3	4.0	17.1
HP6155b	MDC 46_vine 201434	30 m	1373	29.8	1.38	2.61	47.2	4.9	6.7	42.3	40.5	35.6	16.4	5.0	24.1
HP6155c	MDC 46_vine 201434	45 m	1726	22.1	1.42	2.62	45.8	6.1	7.8	39.6	38.0	33.6	16.8	4.4	21.3
HP6156a	MDC46_wheel 20142935	15 m	1078	20.9	1.50	2.62	42.9	5.2	6.5	37.6	36.4	32.9	19.8	3.5	16.6
HP6156b	MDC46_wheel 20142935	30 m	1648	34.5	1.33	2.60	49.0	1.7	3.1	47.4	45.9	39.6	17.5	6.3	28.4
HP6156c	MDC46_wheel 20142935	45 m	1241	39.0	1.29	2.60	50.4	2.0	3.1	48.4	47.3	41.6	17.3	5.7	30.0
HP6157a	MDC 46_alley 20142933	15 m	1709	24.5	1.48	2.60	43.1	1.9	3.2	41.2	39.9	35.9	21.0	4.1	18.9
HP6157b	MDC 46_alley 20142933	30 m	1242	38.1	1.20	2.60	53.9	8.2	10.0	45.8	43.9	37.0	14.9	6.9	29.0
HP6157c	MDC 46_alley 20142933	45 m	1042	36.7	1.25	2.59	51.8	5.1	6.8	46.8	45.0	38.9	16.0	6.1	29.0
HP6158a	MDC 54 20142938	15 m	1640	28.7	1.16	2.57	54.8	5.9	9.5	48.9	45.3	36.0	17.9	9.2	27.4
HP6158b	MDC 54 20142938	30 m	1032	24.3	1.11	2.52	56.1	7.7	13.8	48.4	42.3	33.4	16.8	8.9	25.5
HP6158c	MDC 54 20142938	45 m	1115	21.9	1.10	2.59	57.5	17.2	22.4	40.3	35.1	25.8	13.1	9.3	22.0
HP6159a	MDC 55 20142939	15 m	1727	15.9	1.14	2.62	56.4	28.3	29.5	28.1	26.9	21.7	12.2	5.2	14.7
HP6159b	MDC 55 20142939	30 m	1217	14.0	1.15	2.70	57.6	30.0	32.4	27.6	25.2	20.9	10.3	4.2	14.8
HP6159c	MDC 55 20142939	45 m	1187	14.2	1.31	2.65	50.5	22.6	24.0	27.9	26.5	22.7	11.5	3.8	14.9
HP6160a	MDC 51	15 m	1602	48.1	1.11	2.58	56.8	0.3	2.1	56.5	54.7	44.9	18.3	9.8	36.5
HP6160b	MDC 51	30 m	1707	47.1	1.06	2.60	59.1	6.4	9.0	52.6	50.1	42.0	18.7	8.1	31.4
HP6160c	MDC 51	45 m	1218	40.2	1.18	2.59	54.6	3.8	6.5	50.8	48.1	39.4	19.0	8.7	29.1
HP6161a	MDC 52	15 m	1058	39.0	1.18	2.54	53.7	3.8	6.2	49.9	47.5	34.9	13.4	12.6	34.1
HP6161b	MDC 52	30 m	1303	32.7	1.25	2.58	51.6	8.5	11.4	43.1	40.2	31.2	13.5	9.0	26.7
HP6161c	MDC 52	45 m	1372	37.3	1.19	2.57	53.7	7.8	10.1	46.0	43.6	32.2	15.8	11.4	27.8
HP6162a	MDC 45-vine	15 m	1089	26.0	1.21	2.60	53.6	16.2	18.5	37.4	35.1	29.3	18.7	5.8	16.4
HP6162b	MDC 45-vine	30 m	1003	21.8	1.26	2.60	51.7	16.7	19.7	35.0	32.0	27.0	15.9	5.0	16.0
HP6162c*	MDC 45-vine	45 m	1304	29.2	1.12	2.58	56.7	16.1	18.9	40.6	37.8	31.3	17.5	6.5	20.2
HP6163a	MDC 45-wheel	15 m	1051	35.4	1.13	2.54	55.7	7.1	10.0	48.6	45.7	39.0	19.2	6.8	26.5
HP6163b	MDC 45-wheel	30 m	1606	34.6	1.03	2.54	59.5	13.0	17.5	46.4	42.0	33.9	16.9	8.2	25.2
HP6163c	MDC 45-wheel	45 m	1339	34.5	1.11	2.53	56.2	9.4	12.4	46.9	43.8	36.1	22.7	7.7	21.1
HP6164a	MDC 45-alley	15 m	1588	40.4	0.95	2.54	62.8	14.4	16.5	48.4	46.3	40.3	16.9	6.1	29.4
HP6164b	MDC 45-alley	30 m	1040	35.3	1.09	2.24	51.4	3.8	7.4	47.6	44.0	35.8	17.1	8.2	26.9
HP6164c	MDC 45-alley	45 m	1572	37.7	1.08	2.31	53.3	7.8	10.4	45.6	42.9	35.9	15.5	7.0	27.4
HP6165a	MDC 53	15 m	1210	32.3	1.11	2.56	56.7	16.5	18.5	40.2	38.2	31.7	14.7	6.5	23.5
HP6165b*	MDC 53	30 m	1534	40.7	1.08	2.47	56.2	8.6	11.1	47.6	45.1	38.7	14.1	6.3	31.0
HP6165c	MDC 53	45 m	1593	39.4	1.06	2.62	59.6	15.4	17.1	44.2	42.5	35.5	17.3	7.0	25.2
HP6166a	MDC 49	15 m	1121	36.0	0.80	2.73	70.8	32.8	37.3	38.0	33.5	24.7	16.0	8.8	17.5
HP6166b	MDC 49	30 m	1504	42.4	0.80	2.73	70.8	28.5	34.4	42.3	36.4	28.0	14.6	8.4	21.8
HP6166c	MDC 49	45 m	1733	41.0	0.76	2.77	72.6	33.3	37.8	39.3	34.8	25.1	18.3	9.6	16.5
HP6167a	MDC 50	15 m	1604	34.4	0.74	2.52	70.7	13.9	21.3	56.8	49.4	37.0	14.1	12.4	35.3
HP6167b	MDC 50	30 m	1613	36.9	0.89	2.50	64.3	10.0	14.3	54.2	50.0	41.1	19.7	8.8	30.2
HP6167c	MDC 50	45 m	1636	30.7	0.88	2.54	65.2	10.8	15.1	54.4	50.1	40.1	16.8	10.0	33.3

Note: Results for samples that contained more than 10% stones by volume were recalculated and are presented on the next page in this spreadsheet.

Macro-porosity cited here is determined between total porosity and tension of -5 kPa, for consistency with the National Soils Database of New Zealand (NSD).
Air Filled-porosity cited here is determined between total porosity and tension of -10 kPa. This can be referred to as Macro-porosity. It is important to be aware what tension has been used, paticularly with historical or NSD data.

Macroporosity (and Air-filled porosity) figures marked as <1 indicate instances where the samples were right on the limit of the methodology capability.
These samples have extremely low macro porosity and have presented as negative numbers following calculation of the raw data.
In reality it is impossible for MacroPorosity to exceed Total Porosity hence the macroporosity data has been adjusted to simply indicate samples with extremely low figures.

A visual inspection of the sub-sampled cores yielded the following:

MDC 59 30m (HP6148b): sub-sampled core contained a 8mm diameter stick.
MDC 56 45m (HP6149c), MDC 46_wheel 20142935 15m (HP6156a), MDC 53 45m (HP6165c): differed in colour from its replicates.
MDC 58 15m (HP6153a), MDC 60 20142944 45m (HP6154c), MDC 45-vine 15m and 30m (HP6162a and b), MDC 45-wheel 30m (HP6163b), MDC 45-alley 15m (HP6164a), MDC 53 15m (HP6165a)
: these samples showed disturbance due to presence of stones. The sub-sampled cores were partially repacked after the removal of large stones.
MDC 46_alley 20142933 (HP6157a): differed in colour from its replicates. Looked like it contained subsoil.
MDC 54 20142938 45m (HP6158c), MDC 55 20142939 (HP6159a-c): these samples showed disturbance due to the prescence of stones.
MDC 53 15m and 30m (HP6165a and b): contained subsoil.

*Adjusted fo stones: Soil Description Handbook (Milne *et al*, 1991) recommends core sampling as appropriate for soils with less than 15% stones (stone refers to particles >2mm).
After the completion of whole soil moisture release analysis, the cores were broken down and the volume and mass of stones was assessed.
It was decided 10% stones by volume be the threshold where data should be re-calculated to account for the prescence of stones in the core samples.

Checked by: John Claydon
Laboratory Manager

Analyst: DT

Aggregate stability data 2014 – Landcare Research

Soil Physics Laboratory
Analytical Report

Landcare Research
Manaaki Whenua

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Job Number: PJ14006

Customer: Marlborough District Council
Rachel Rait

Date Received: 16/09/2014
Date Reported: 18/12/2014

Sample Name	MDC 47
Sample ID	PP14-0257
Net % aggregates larger than:	
2 mm	2.6
1 mm	9.6
0.5 mm	19.1
Mean weight diameter	0.46

Reference:
Gradwell MW 1972. Water stability of soil aggregates – C5.A. Wet-sieving test: methods for physical analysis of soils. New Zealand Soil Bureau Scientific Report 10.

John Dando, Soil Physics Laboratory Manager

Soil chemical data 2014 – Hills Laboratory

R J Hill Laboratories Ltd																					

Laboratory Job Number:	1325399																				
	pH	Olsen P	AMN	C/N Ratio	Total C	Total N	Total Zn	Total Cu	Total Cr	Total As	Total Pb	TotalNi	Total Hg	Total Cd	Potassium	Calcium	Magnesium	Sodium	CEC	Total BS	Volume Weight
		mg/L	µg/g		%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	me/100g	me/100g	me/100g	me/100g	me/100g	%	g/mL
Sample Name																					
MDC47	6	7	74	9.8	2.3	0.23	42	< 4	14.6	1.7	6.9	8.8	0.04	0.14	0.11	5.7	1.19	0.25	12	58	1.04
MDC48	5.7	10	127	11.5	3.5	0.31	43	4	19.6	2	6.9	11.1	0.03	0.12	0.43	4.9	1.72	0.35	15	50	0.96
MDC56	6	12	120	9.1	3.5	0.39	60	8	17.8	2.8	8.7	12.8	0.03	0.18	0.31	8.5	1.34	0.14	17	61	0.93
MDC57	5.5	50	130	8.1	4.2	0.52	52	9	14.1	3.7	7.5	9.8	0.02	0.22	1.89	7.6	1.98	0.09	22	53	0.93
MDC58	5.8	17	133	12.5	4.1	0.33	61	10	14.5	4.3	10.3	10.1	0.03	0.15	0.75	7.9	2.14	0.08	20	55	0.86
MDC59	5.5	20	83	13.6	3.6	0.27	35	7	14.5	1.3	8.2	10.5	0.02	0.11	0.37	6.6	1.78	< 0.05	20	44	0.91
MDC60	5.5	9	145	11.1	4.1	0.37	38	8	18.4	1.8	8.2	12.7	0.02	0.14	0.41	5	1.25	< 0.05	17	39	0.82
MDC46_Alley	6.5	7	121	11.9	2.6	0.22	46	5	19.2	2.3	8	10.2	0.03	0.15	0.17	9.6	1.48	0.28	15	75	0.93
MDC46_Vine	6.7	21	96	11.6	3	0.26	52	6	17.6	3.9	8.4	10.3	0.03	0.17	0.45	10.1	2.09	0.28	15	89	0.93
MDC46_Wheel	6.5	16	107	9.5	2.5	0.26	50	5	17.3	2.4	8.1	9.7	0.03	0.15	0.32	8.8	1.45	0.31	13	85	1.02
MDC54	5.5	26	122	11.3	4.1	0.37	67	11	14	5.3	14.9	10	0.02	0.08	0.98	4	1.2	0.06	16	38	0.89
MDC55	5.9	17	65	15.9	2.6	0.16	67	10	15.9	4.2	16.6	13.7	0.02	0.07	0.71	5.6	1.43	0.05	13	60	1.07
MDC49	4.9	16	104	15.7	7.1	0.45	46	< 4	22	2.6	34	11.9	0.05	0.03	0.34	1	0.36	0.06	24	7	0.67
MDC50	5.6	21	179	11.7	8.4	0.72	43	7	26	3	11.9	14.4	0.04	0.17	0.44	9.7	0.51	< 0.05	26	42	0.7
MDC51	5.8	8	107	11.2	2.8	0.25	43	11	41	2.9	8.9	19.9	0.02	0.24	0.25	10.4	0.74	0.06	21	54	0.77
MDC52	5.2	11	111	11.5	2.8	0.24	15	5	36	2	5.8	17.6	0.02	0.06	0.15	2.5	0.51	< 0.05	11	28	0.85
MDC53	5.1	4	69	12.9	3.2	0.24	47	16	57	5	12	33	0.02	0.03	0.4	3.2	2.07	< 0.05	17	34	0.81
MDC45_alley	6.7	30	128	11.5	5.1	0.44	78	8	26	3.6	13.8	15	0.03	0.2	1.55	14.3	1.68	0.08	22	78	0.83
MDC45_vine	6.5	35	92	11.6	4.1	0.35	75	7	23	3.6	12.1	13.3	0.03	0.2	1.13	12.4	1.37	0.08	19	80	0.92
MDC45_wheel	6.4	39	132	9.5	5.1	0.54	77	9	25	3.7	12.4	14.7	0.03	0.19	1.57	14.2	1.67	0.08	22	81	0.83