HAWKE'S BAY
REGIONAL COUNCIL

Soil Quality of Exotic and Indigenous Forests in Hawkes Bay 2015/2016

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Hawke's Bay Regional Council

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TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

Hawke's Bay Regional Council (HBRC) are responsible for monitoring the soil quality of Hawke's Bay region as part of their obligations for State of the Environment (SoE) reporting. HBRC reviewed their soil monitoring programme in 2006 (Pearson & Reid, 2006). This provided a framework on which to base a selection process for sites that represent Hawke's Bay, based on land form, soil order, soil types and land use. It also prioritised the soil quality indicators to be used in this programme.

In 2009, the National Land Monitoring Forum (LMF) produced robust guidelines from which councils can produce nationally consistent land monitoring procedures and reporting. In accordance with the identified reporting requirements, HBRC have engaged LEI to assist with fieldwork and report on soil quality parameters. Information presented in this report examines the soil quality of indigenous and exotic forestry land in Hawke's Bay. Soil quality is assessed in accordance with the recommendations of Pearson and Reid (2006) and the LMF guidelines.

Indigenous forest refers to permanent stands of native vegetation. Typically, these areas have not had any other land use. Exotic forest refers to plantations grown for harvest of timber. The land is extensively managed for both forest types, but may undergo extensive disturbance at planting and harvest of exotic forest.

Soil sampling for the forest sampling round occurred in November 2015. Sites were visited by LEI staff and HBRC staff. Where possible, indigenous forest sites were chosen where no other land use had occurred, and exotic forests were chosen where canopy closure had occurred and harvest was more than five years away.

Five sites were sampled from indigenous forest and twelve sites were sampled under exotic forest. The sites selected represented three soil groups (Hewitt, 1992). Results from the analysis of soil from each site enabled the following conclusions to be made:

- In general, soil quality in Hawke's Bay indigenous and exotic forest sites is suitable for the current forestry land use;
- Soil fertility is expected to be low, reflecting the nutrient cycling that occurs in forests following canopy closure. As a result, low Olsen P is not considered to be limiting to the current land use;
- Soil physical condition reflects the dominant land forms (steep and rolling slopes) and vegetation, resulting in high macroporosity and low bulk density on a number of sites; and
- Low fertility and the soil physical condition are suitable for the forestry land use.

Recommended actions coming from this report include:

- Managers of the properties sampled should be informed of the soil quality on their properties. No remedial activity is recommended following this sampling round; and
- The same sites should be resampled within five years (prior to harvest for exotic forest sites) and at ongoing intervals to develop a long-term record of soil quality indicator performance over time.

2 INTRODUCTION

2.1 Purpose

This report provides Hawke's Bay Regional Council (HBRC) with an interpretive soil quality report based on laboratory and field data.. This information is intended to contribute to the Regional council's State of the Environment reporting obligations.

2.2 Background

HBRC maintains a database of soil condition from different land uses representative of Hawke's Bay region. This database began with the "500 Soils Project" co-funded with the Ministry for the Environment (MfE) during 1999 - 2000. MfE ceased involvement in the project in 2001, with the understanding that regions would continue monitoring and at a future date, the 500 Soils Project sites would be resampled.

HBRC reviewed their soil monitoring programme in 2006 (Pearson & Reid, 2006). This provided a framework on which to base a selection process for sites that represent soils of Hawke's Bay based on land form, soil order, soil types and land use. It also prioritised the soil quality indicators. The current report focuses solely on forest soils, both indigenous and exotic.

In 2009, the National Land Monitoring Forum (LMF) produced robust guidelines from which councils can produce nationally consistent land monitoring procedures and reporting. In accordance with the identified reporting requirements, HBRC have engaged LEI to assist with field work and report on soil quality parameters. Information presented here examines soil quality of forestry land use in Hawke's Bay. Soil quality is assessed in accordance with the recommendations of Pearson and Reid (2006) and the LMF guidelines.

2.3 Scope

This report follows on from previous soil quality reports produced by Lowe Environmental Impact Ltd (LEI) for the HBRC on extensive pastoralism (2011), intensive pastoralism (2013), cropping (2014), orchards (2015) and vineyards (2015). For consistency, this report maintains a similar format and methodology for assessing soil quality as that used in the previous reports. The scope of this report is to describe the soil quality of land used for forestry in the Hawkes Bay region. In particular it details:

- Section 3: Discusses the soil quality monitoring framework;
- Section 4: Methods used to collect data;
- Section 5: Results from data collected with brief written interpretation;
- Section 6: Discussion;
- Section 7: Conclusions; and
- Section 8: Recommendations.

3 SOIL QUALITY AND LAND USE

3.1 Soil Quality Monitoring in Hawke's Bay

As in previous reports (LEI, 2011, 2013, 2014, 2015a and 2015b), soil quality is an important indicator of the state of the environment. A clear procedure for the investigation of soil quality in New Zealand has been established. This report uses guidelines prepared by the National Land Monitoring Forum (LMF, 2009) for the measurement and interpretation of soil quality. It is complimented by information from previous reports on soil quality for Hawke's Bay region, which have been reviewed and referenced throughout this report.

3.2 Land Use Definition

The adoption of indigenous forest and exotic forest as land uses is in line with the LMF guidelines. The land use categories are defined so that they can be aggregated back to the New Zealand Land Cover Database.

Indigenous forest refers to permanent stands of native vegetation. Typically, these areas have not had been under any other land use. Exotic forest refers to plantations grown for harvest of timber. Exotic forests are extensively managed but may undergo significant disturbance during planting and harvesting.

3.3 Soil Quality Indicators

Research on the assessment of soil quality is extensive. In line with the recommendations of Pearson and Reid (2006), the adopted indicators for Hawke's Bay region follow the convention of the "500 Soils Project" (Hill, *et al.*, 2001). The identified soil quality indicators are as follows:

Priority One: The Minimum Data Set

- Soil pH or soil acidity;
- Olsen Phosphorous (P);
- Total carbon (C) and nitrogen (N);
- Potentially mineralisable N;
- Bulk density;
- Macroporosity; and
- Aggregate stability (cropping soils).

The Priority One indicators are considered to represent the minimum parameters to be measured in order to assess soil health. These indicators are the focus of the monitoring programme described in this report regarding the health of forest soils in Hawke's Bay.

Priority Two: Extra Measurements - Visual Soil Assessment (VSA; Shepard, 2000)

- % bare ground;
- % area of crusted soil and crust thickness;
- % area damaged soil surface; and
- Thickness of organic matter thatch.

Priority Two indicators provide a qualitative assessment of soil condition but are not typically used for forest soils. These measurements can indicate if soil quality is degraded. Priority Two indicators have not been evaluated for the 2015 forest sites.

Priority Three: Extra Measurements

- Exchangeable cations and cation exchange capacity;
- Trace elements: arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), zink (Zn), uranium (U), fluoride (F);
- DDT; and
- Hot water extractable C.

Priority Three indicators provide information that supports interpretation of Priority One indicators and adds detail about fertility and contamination. While Priority One indicators describe soil quality in general terms, i.e. as relates to any land use, Priority Three indicators help to determine the soil quality as it relates to the specific site activity.

3.4 Trace Element and Organochlorine Pesticide Monitoring

Trace element and organochlorine pesticide measurement corresponds to the Priority Three indicators. While not considered fundamental to the measurement of soil quality, they give important information about soil health on an individual property, and may identify sites where land use has had a detrimental effect on soil quality. If data from several properties exceeds guidelines for the trace elements of particular concern (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg, U, F), it is recommended to pursue further investigation (Chapter 5: LMF, 2009). Organochlorines such as DDT and its metabolites are an indicator of land use impacts since they do not occur naturally. In addition, the presence of elevated levels of organochlorine pesticides and trace elements indicates a limitation to land uses on the site.

Trace elements of concern that have the highest potential to be elevated are Cd, F^- and U. They are known to accumulate in the soil when superphosphate has been applied. Copper is used in anti-fungal treatments for pine plantations and is known to have detrimental effect on soil biota, and poses a risk if transported to the aquatic environment.

3.5 Historical State of Hawke's Bay Soils

Previous LEI reports (LEI, 2011, 2013, 2014, 2015a and 2015b) and the New Zealand Soil Health Report Card (NZSHRC; MOE, 2010) have identified the soil management challenges for Hawke's Bay region as:

- Poor aggregate stability (all land uses);
- Low macroporosity (intensive pasture);
- Low carbon reserves (cropping)
- General fertility (extensive pasture); and
- Phosphorus status (extensive pasture).

An evaluation of the soil monitoring programme in 2014 identified that the issues listed above were still present in Hawke's Bay, but further degradation had not been observed.

4 METHODOLOGY

4.1 Site Selection

The method for site selection follows the recommendation of LMF (2009) for determining if a site is representative of a land use type, and whether a site is suitable for establishment of long-term monitoring. Pearson and Reid (2006) described the range of soils and land use activities in Hawke's Bay region, and provided recommendations for sampling of soils under forestry.

In order to determine locations for the establishment of soil quality monitoring sites, HBRC utilised existing soil and land use maps of the region. Overlays of land use and soil type were applied to property boundaries. HBRC identified a representative property for each soil type. As suggested by Pearson and Reid (2006), property owners were provided with questionnaires to provide detailed and up to date site information. Site information included land use history, current management practices and general site information.

Soil quality is not a static measure and therefore, revisiting sites is important for long-term soil quality monitoring.. A key consideration for site selection was the ability to resample sites every 5 years. Criteria for the selection of exotic forestry sites was that trees were at least 5 years from harvest but had reached full canopy closure.

4.2 Establishment of a Monitoring Site

In brief, sites were located so that no part of the sampling transects were affected by tracks, streams, drainage ditches, buildings, fire sites, erosion scars or other disturbed areas.

A 50 m transect was marked out. GPS co-ordinates were taken and soil pits excavated at 0 m, 25 m and 50 m along the transect. Soil was described to a depth of around 50 cm for two pits and to around 100 cm at one pit. Full soil descriptive information is provided in Appendix A.

4.3 Observations on Site Selection and Site Establishment

Soil quality sampling of forestry sites occurred in November 2015. For exotic forestry, sites were selected where the trees had reached canopy closure but were at least five years from harvest. For the indigenous forest sites, where possible, old growth sites were selected in preference to areas that had been retired from other land uses.

4.4 Sampling and Analysis

Soil sampling and analyses followed the guidelines prepared by the LMF (2009). The draft LMF guidelines are based on the protocols established by the 500 Soils Project (Hill *et al.*, 2003). A summary of the procedure for sampling and analysis is as follows.

4.4.1 Sampling for Soil Physical Indicators

For bulk density, porosity, macroporosity, field capacity and available water capacity, intact cores (10 cm diameter x 7.5 cm depth) for analysis of soil physical characteristics were taken at three points along each transect at 0, 25 and 50 m.

4.4.2 Sampling for Soil Chemical and Microbiological Indicators

Soil cores with a diameter 2 cm were taken every 2 m and to a depth of 10 cm along each transect and placed together as a composite sample in a sealable bag for chemical analysis. These samples were used for analysis of organic matter and soil nutrient levels.

A second composite sample was also collected using the same procedure outlined above and analysed for trace elements and persistent organic contaminants.

4.4.3 Sample Handling and Transport

Samples collected for chemical and microbial analysis were packed in sealed bags and placed in chilly bins to be kept cool, until they were sent to Hill's Laboratories for analysis. If samples were not tranported immediately to a laboratory for analysis, samples were transferred to a fridge for storage until they could be sent on to the laboratory. Intact cores for the physical analysis were stored and transported in padded crates.

4.4.4 Sample Analysis

The samples sent to Hill Laboratories were analysed for:

- Basic soil test: pH, Olsen P, exchangeable cations, CEC, base saturation;
- Organic soil profile: Available N, anaerobically mineralisable N (AmN), organic matter, total C, total N, C/N ratio, AmN/N ratio;
- Heavy metal screen (for trace elements): As, Cd, Cr, Cu, Ni, Pb, Zn, Hg;
- Organochlorine pesticide screen;
- Total uranium (Ur); and
- Total fluoride (Fl-).

Analyses conducted at the Landcare Research laboratory were:

- Bulk density;
- Macroporosity;
- Particle density;
- Total porosity;
- Field capacity: soil moisture content when all macropores have drained; and
- Available water capacity (AWC).

4.5 Data Presentation

All data is expressed as received from Hills Laboratories. Where necessary, recalculation of data to different units was made to enable comparison to historical data i.e. the analysing laboratories typically express results on a gravimetric basis (mass/mass basis), however for some parameters, as they relate to soil quality, it is considered more appropriate to compare them on a volumetric basis (mass/volume).

Available N data is received from the laboratory expressed per 150 mm of topsoil depth. Results given in the following sections have been adjusted to reflect the 100 mm depth that was sampled for this soil quality monitoring programme.

5 RESULTS

5.1 Soils and Sites

Five sites were sampled from indigenous forest and a further twelve sites were sampled under exotic forest. Table 5.1 lists the soil types at each sample site and the soil order/group to which they belong.

Of the eight soil orders chosen to represent the region (Pearson & Reid, 2006), three soil orders are represented in the forest soils sampled for this study.

Table 5.1: Soil Quality Monitoring Sites

Site No*	Soil Type	Soil Order*	Dominant forest species
IF01	Matamau	Brown	Lowland Podocarp
IF02	Ruahine	Brown	Mountain Beech
IF03	Kaweka	Pumice	Mountain Beech
IF04	Gisborne	Pumice	Nikau, tawa, kohkohe
IF05	Mahoenui	Pallic	Broad leaf, podocarp, Nikau
EF01	Crownthorpe	Pallic	Pinus Radiata (20 yo)
EF02	Te Apiti	Pallic	Pinus Radiata (15 yo)
EF03	Waipawa	Pallic	Pinus Radiata (5 yo)
EF04	Gwavas	Brown	Pinus Radiata (15 yo)
EF05	Ruahine	Brown	Pinus Radiata
EF06	Te Apiti	Pallic	Pinus Radiata (20 yo)
EF07	Tuai	Pumice	Pinus Radiata (20 yo)
EF08	Hangaroa	Pumice	Pinus Radiata
EF09	Mahoenui	Pallic	Pinus Radiata
EF10	Taupo/Kaweka integrade	Pumice	Pinus Radiata (12 yo)
EF11	Taupo (disturbed)	Pumice	Pinus Radiata (15 yo)
EF12	Gisborne sandy loam	Pumice	Pinus Radiata (20 yo)

* The prefix "IF" refers to indigenous forest sites and "EF" refers to exotic forest sites
** New Zealand Soil Classification (Hewitt, 1992)

Soil profile and site descriptions are provided in Appendix A. The dominant landform for the forest sites is rolling and steep hill country and as a result, a number of potential sampling locations showed signs of mass movement. Where possible, the sampling transect was established in such a way as to avoid recent or historic mass movement. However, in some locations, a thick layer of litter was present and may have masked erosion features.

5.2 Analysis Results

Soil chemistry, physical data, trace element levels and agrichemical contaminants are shown in Tables 5.2 to 5.4 below. Raw data received from the analysing laboratories are given in Appendix B.

Table 5.2: Soil Chemical Characteristics of Hawke's Bay Forest Sites Sampled in 2015

Site	Soil Type	pH	CEC	Total C		Total N		C/N	Olsen P	Base Saturation	Anaerobically Mineralisable N		Available N	K	Ca	Mg	Na
			me/100g	% m/m	mg/cm³	% m/m	mg/cm³	ratio	mg/L	%	µg/g	µg/cm³	kg/ha	me/100g			
IF01	Matamau	6.4	30	6.6	56	0.57	5	11.6	**6**	85	154	131	123	1.07	20	4.25	0.09
IF02	Ruahine	4.7	45	17.1	78	0.63	3	27.0	**2**	5	**276**	126	111	0.42	1	0.76	0.21
IF03	Kaweka	5	24	9.5	82	0.71	6	13.4	**3**	8	134	116	84	0.38	0.8	0.55	0.08
IF04	Gisborne	6.4	27	5.4	50	0.36	3	14.9	**3**	84	116	107	93	0.47	18.9	3.47	0.22
IF05	Mahoenui	5.5	27	5.7	51	0.38	3	14.9	**4**	55	112	100	87	0.5	9.1	4.77	0.36
EF01	Crownthorpe	5.4	20	3.7	44	0.33	4	11.1	**7**	42	93	110	73	0.65	4.8	2.46	0.39
EF02	Te Apiti	5.4	24	4	36	0.42	4	9.4	31	49	122	110	95	1.86	7.6	2.26	0.24
EF03	Waipawa	5.4	22	3.5	40	0.37	4	9.4	34	58	107	123	79	0.84	10.2	1.79	0.11
EF04	Gwavas	5.8	27	7.6	65	0.55	5	13.8	**6**	45	63	54	45	1.09	8.6	2.25	0.14
EF05	Ruahine	6	27	8.9	62	0.44	3	20.1	**4**	36	145	102	83	0.68	7.1	2.16	0.1
EF06	Te Apiti	6.4	22	3	39	0.27	4	11	**9**	100	58	75	49	0.36	20.2	1.61	0.19
EF07	Tuai	6.1	17	6.5	32	0.3	1	21.7	**3**	44	86	43	50	0.64	5.4	1.44	0.11
EF08	Hangaroa	5.8	17	3.6	37	0.3	3	12.1	**12**	45	59	60	43	0.72	4.9	1.88	0.22
EF09	Mahoenui	5.5	26	3.6	33	0.4	4	9.0	**17**	62	117	107	91	0.95	12.4	2.51	0.16
EF10	Taupo/Kaweka integrade	5.8	20	4.5	39	0.31	3	14.7	**6**	50	70	60	45	0.84	7.4	1.98	0.06
EF11	Taupo (disturbed)	5.5	19	5.4	48	0.27	2	19.6	**4**	22	118	105	80	0.41	2.8	0.93	0.06
EF12	Gisborne	5.8	22	7.3	43	0.51	3	14.4	**3**	25	84	50	46	0.43	4.1	0.91	0.11

* Items in bold fell outside the target range for that land use and soil order (Hill & Sparling, 2009)

Table 5.3: Soil Physical Characteristics of Hawke's Bay Sites Sampled in 2015

Site	Soil Type	Dry bulk density	Particle density	Porosity	Macro-porosity -10 kPa	Field capacity	AWC
		(g/cm^3)	(g/cm^3)	(%)	(%)	(%)	(%)
IF01	Matamau	0.85	2.52	66	25	42	19
IF02	Ruahine	**0.46**	2.35	81	**45**	36	18
IF03	Kaweka	0.86	2.50	65	28	38	16
IF04	Gisborne	0.93	2.60	64	28	36	21
IF05	Mahoenui	0.89	2.57	65	29	37	20
EF01	Crownthorpe	1.18	2.50	53	16	37	20
EF02	Te Apiti	0.90	2.20	58	**32**	26	11
EF03	Waipawa	1.15	2.50	54	17	37	12
EF04	Gwavas	0.85	2.44	65	30	36	13
EF05	Ruahine	0.70	2.48	72	**34**	38	12
EF06	Te Apiti	1.30	2.60	50	19	31	18
EF07	Tuai	**0.50**	2.25	78	**44**	34	22
EF08	Hangaroa	1.02	2.48	59	27	32	20
EF09	Mahoenui	0.91	2.50	64	22	41	20
EF10	Taupo/Kaweka integrade	0.86	2.36	64	**34**	29	14
EF11	Taupo (disturbed)	0.89	2.41	63	25	39	19
EF12	Gisborne	**0.59**	2.31	74	**38**	36	22

* Items in bold fell outside the target range for that land use and soil order (Hill & Sparling, 2009)

Table 5.4: Trace Element Levels of Hawke's Bay Sites Sampled in 2015

Site	Soil Type	Individual Tests		Heavy metals, screened As, Cd, Cr, Cu, Ni, Pb, Zn, Hg							
		Total Recoverable Uranium	Fluoride	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
IF01	Matamau	0.76	136	3	0.34	15	16	9.2	< 0.10	8	80
IF02	Ruahine	0.73	210	5	< 0.10	15	14	13.8	0.2	5	31
IF03	Kaweka	0.77	270	7	< 0.10	15	18	22	0.12	9	59
IF04	Gisborne	0.42	149	8	< 0.10	16	5	7.5	< 0.10	13	42
IF05	Mahoenui	0.43	132	6	< 0.10	15	5	6.9	< 0.10	11	36
EF01	Crownthorpe	0.45	186	2	0.1	6	4	6.7	< 0.10	4	25
EF02	Te Apiti	0.4	171	3	0.18	4	10	5.8	< 0.10	3	43
EF03	Waipawa	0.86	240	3	0.68	7	10	7.2	< 0.10	10	66
EF04	Gwavas	0.46	149	3	0.16	11	12	9	< 0.10	6	57
EF05	Ruahine	0.61	179	4	< 0.10	14	16	10.4	0.11	7	48
EF06	Te Apiti	0.52	220	4	0.13	12	3	7.6	< 0.10	9	33
EF07	Tuai	0.28	260	< 2	< 0.10	< 2	2	4.2	< 0.10	< 2	21
EF08	Hangaroa	0.37	260	< 2	0.1	5	< 2	4.9	< 0.10	4	25
EF09	Mahoenui	0.79	270	3	0.27	11	9	8.6	< 0.10	12	55
EF10	Taupo/Kaweka integrade	0.43	280	3	0.17	6	6	7.1	< 0.10	3	38
EF11	Taupo (disturbed)	0.52	220	3	0.11	9	6	6.4	< 0.10	5	34
EF12	Gisborne	0.52	250	3	0.13	5	5	5.6	< 0.10	3	27

5.3 Priority One Indicators

The results from the soils analysed have been compared to the interpretative frameworks developed by the LMF expert panel (Hill & Sparling, 2009) (referred to in this report as the Framework). The Framework provides terms to categorise the results and target ranges or critical limits.

5.3.1 Soil pH

Soil pH results are shown in Figure 5.1. The target range for forest soils is pH 3.5 to 7.6 for all except Organic soils, of which none were sampled. All sites were within the target range for soil pH. The target range for forestry soils is broad compared to other land uses.

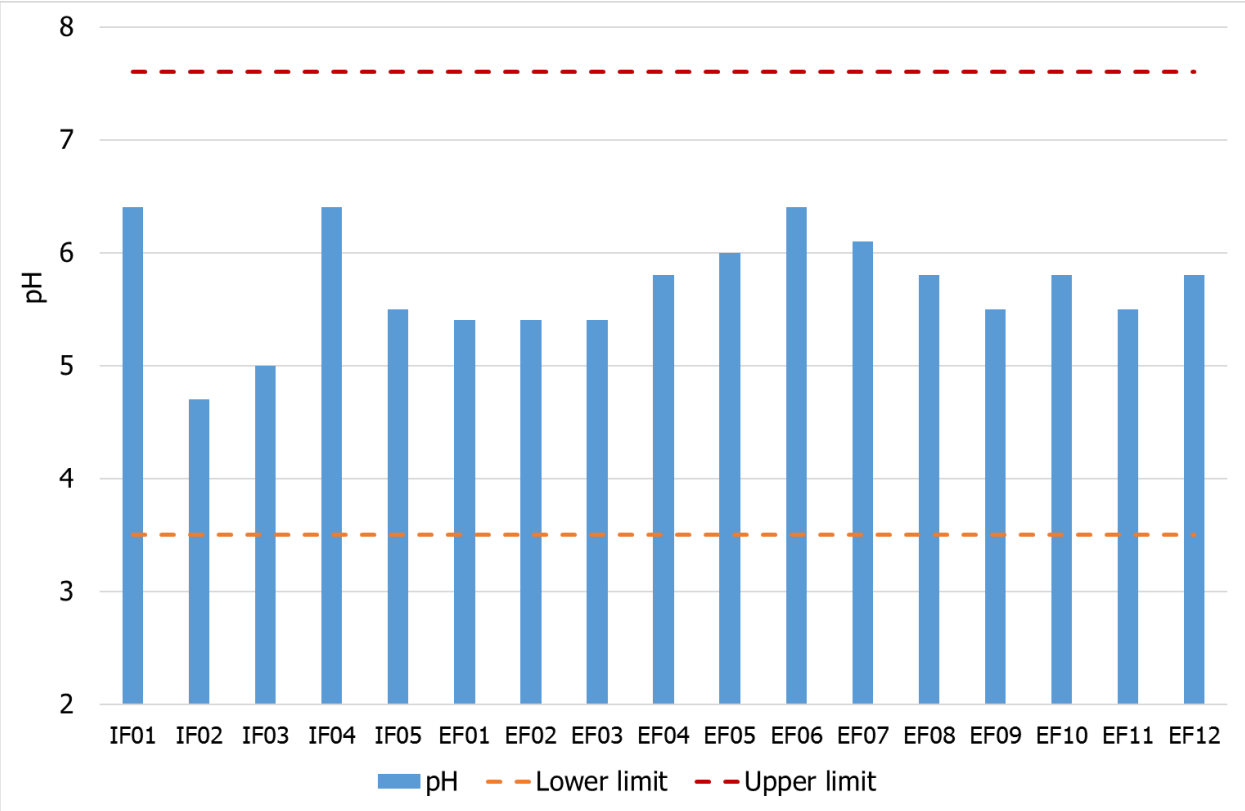

Figure 5.1: Soil pH for Hawke's Bay Forest Sites Sampled in 2015

5.3.2 Soil Total Carbon

Soil total carbon results are shown in Figure 5.2. The target range for soils is dependent on the soil order. The target range for the soils sampled include the following:

- Pumice soils: >2%; and
- Pallic, Brown soils: >2.5%.

All sites met the target for soil total carbon. This reflects the long periods with no soil disturbance that occur under forestry, and the accumulation and decomposition of litter. Sites with the lowest total carbon tended to be Pallic soils, which are typically low carbon soils.

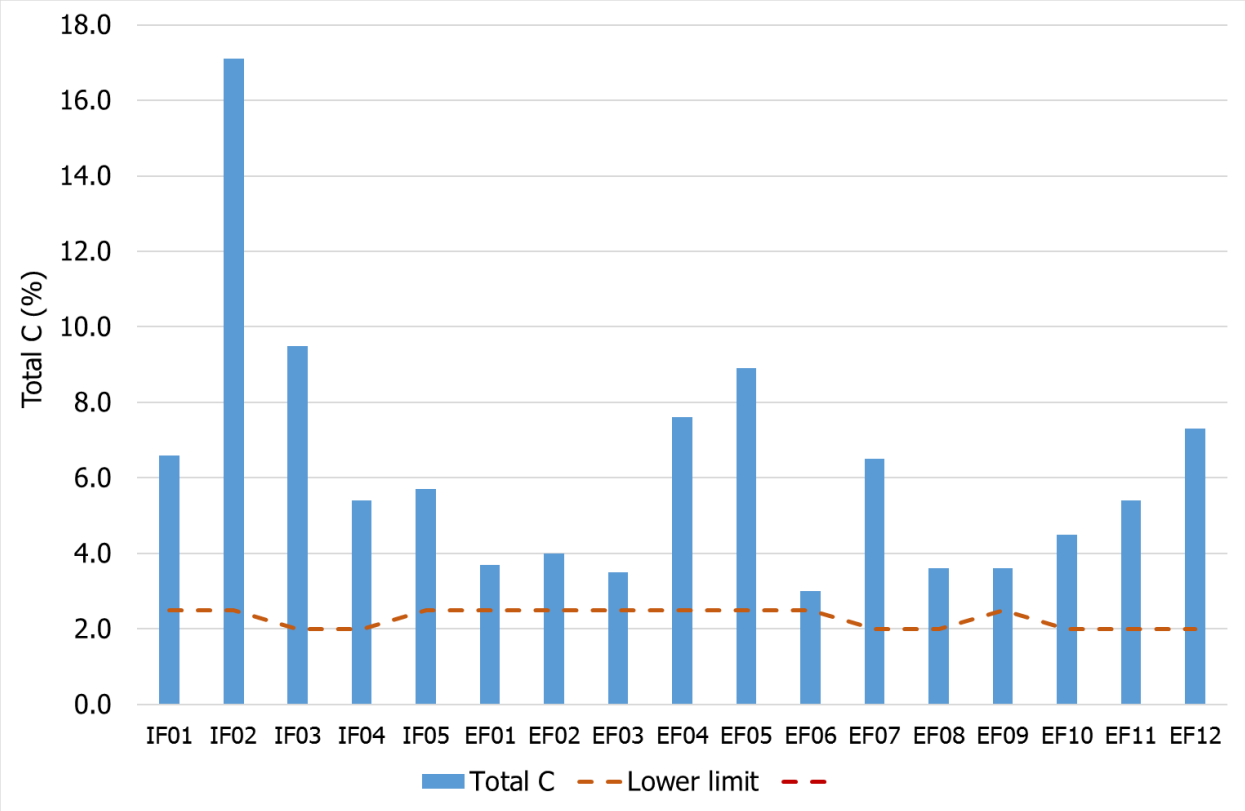

Figure 5.2: Soil total carbon for Hawke's Bay Forest Sites Sampled in 2015

5.3.3 Soil Total Nitrogen

Soil total nitrogen results are shown in Figure 5.3. There are no sites which had total nitrogen below the target of 0.1% for forest soils. The highest total nitrogen results were measured in indigenous forest which reflects the undisturbed nature of the soil as well as the accumulation and breakdown of forest litter.

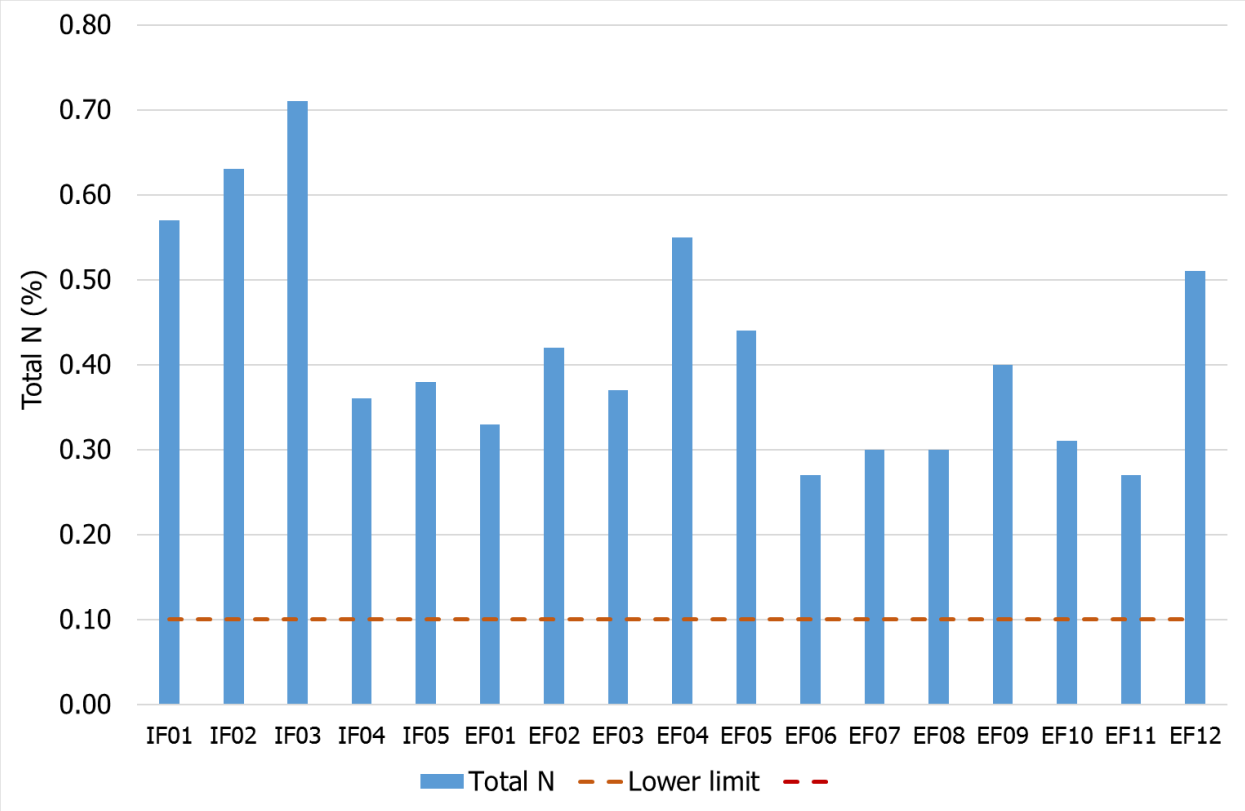

Figure 5.3: Soil total nitrogen for Hawke's Bay Forest Sites Sampled in 2015

5.3.4 Anaerobically Mineralisable Nitrogen

Anaerobically mineralisable nitrogen (AmN) results are shown in Figure 5.4. All sites are within the target range of 20 – 175 kg mg/kg except for IF02 which is higher than the target range. IF02 was located at high altitude, appeared to be a high moisture site, and had a topsoil dominated by decomposing litter and moss. High AmN may indicate a risk for nitrogen leaching, however, high total carbon at IF02 indicates N leaching is unlikely.

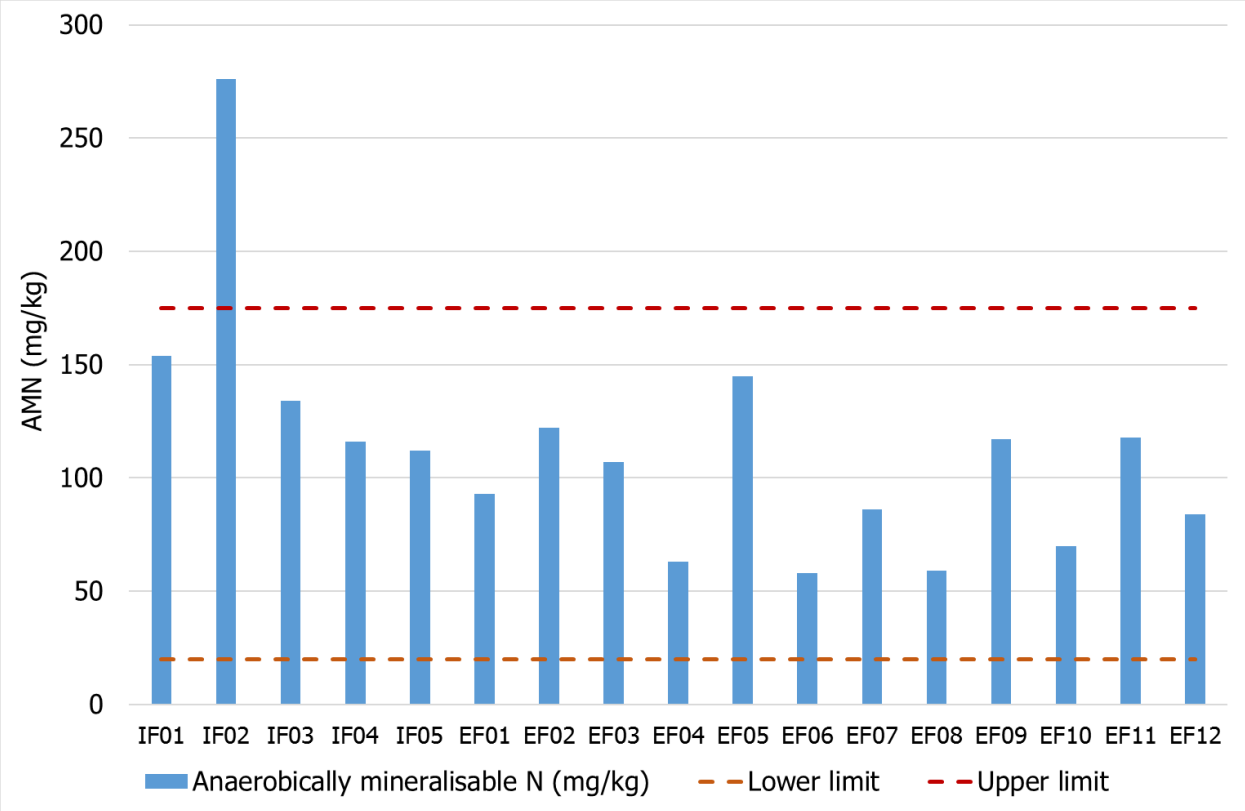

Figure 5.4: AmN for Hawke's Bay Forest Sites Sampled in 2015

5.3.5 Available Nitrogen

When the anaerobically mineralisable N results are adjusted for each site's bulk density and expressed on a per hactare basis, the results can be expressed as Available N. Available N is shown in Figure 5.5 below for the forest sites. Lower available N results occurred in exotic forest sites compared to indigenous forest sites. This is likely a result of longer periods of organic matter accumulation in indigenous forests compared to exotic forests. Longer periods of organic matter accumulation is likely tolead to an increase in the soil nitrogen pool over time.

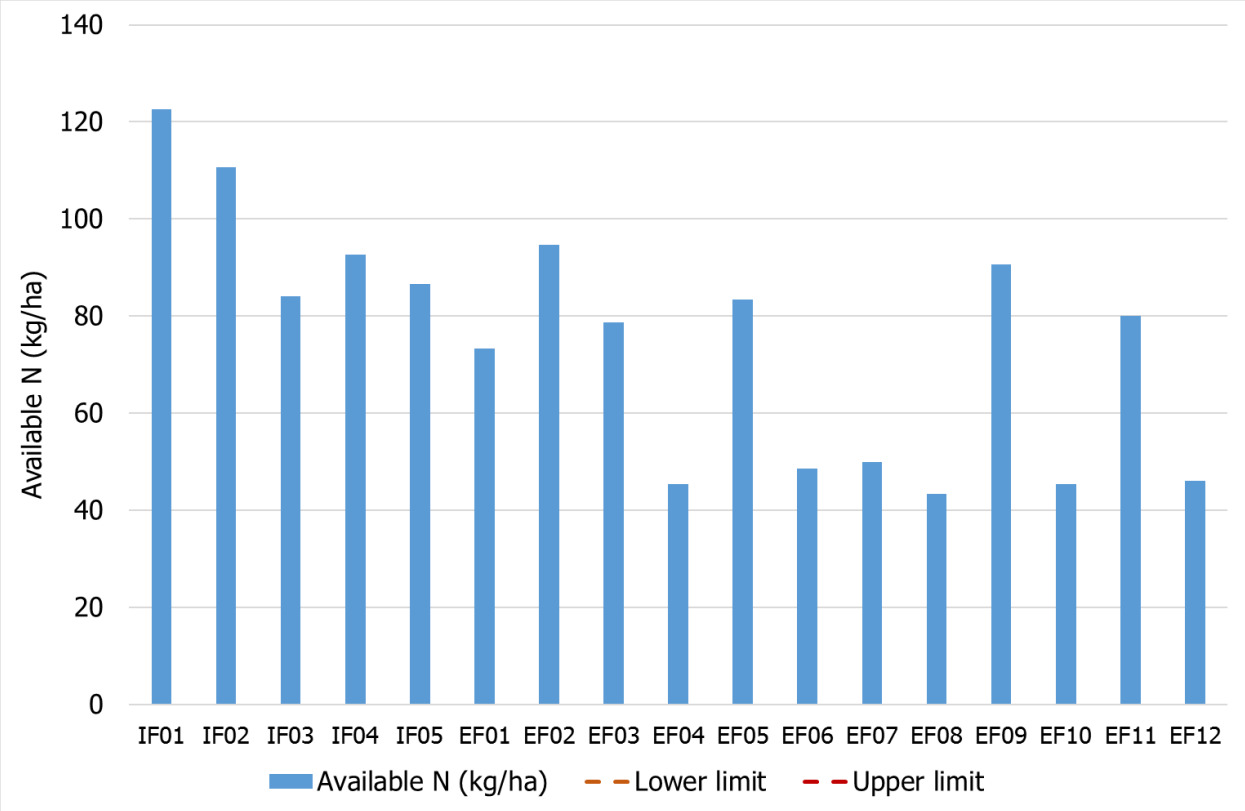

Figure 5.5: Available nitrogen for Hawke's Bay Forest Sites Sampled in 2015

5.3.6 Olsen Phosphorus

Figure 5.6 shows the Olsen P results for the forest sites. The target range for the forest land use is 20 - 100 mg/L for the soil types sampled. Only two of the forest sites (EF02 and EF03) had Olsen P levels within the target range. EF02 is within a pastoral farm and may have received fertiliser, or have high phosphorus reserves in the soil from prior land use. EF03 was previously operated as a pastoral farm and may have phosphorus reserves due to the prior land use. Furthermore, trees were planted approximately 5 years prior to sampling and therefore recent phosphate fertilizer application is likely to have taken place.

Low Olsen P at the remainder of the exotic forestry sites is likely to reflect low natural phosphorus fertility and low inputs of nutrients following canopy closure. The indigenous forest sites are likely to have similarly low natural phosphorus fertility as the only sources of nutrients include atmospheric deposition and animals.

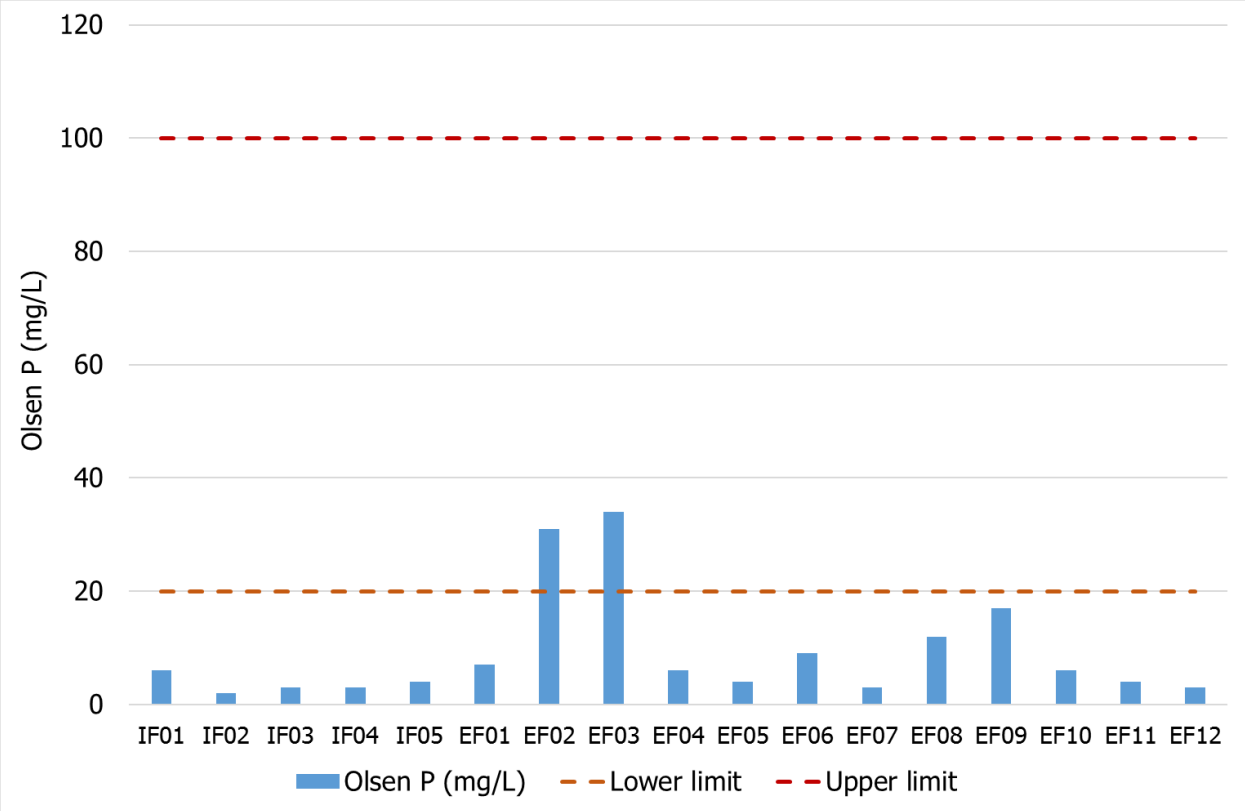

Figure 5.6: Olsen phosphorus for Hawke's Bay Forest Sites Sampled in 2015

5.3.7 Carbon : Nitrogen Ratio

Figure 5.7 shows the C:N ratio results for the forest sites. The sites predominantly had a C:N ratio in a range considered to favour mineralisation of nitrogen for plant uptake (25 or less). The highest C:N ratio was measured at site IF02, and this trend is consistent with the total carbon and AmN results. It is likely the high result reflects the dominance of decomposed leaf litter in the topsoil at this site.

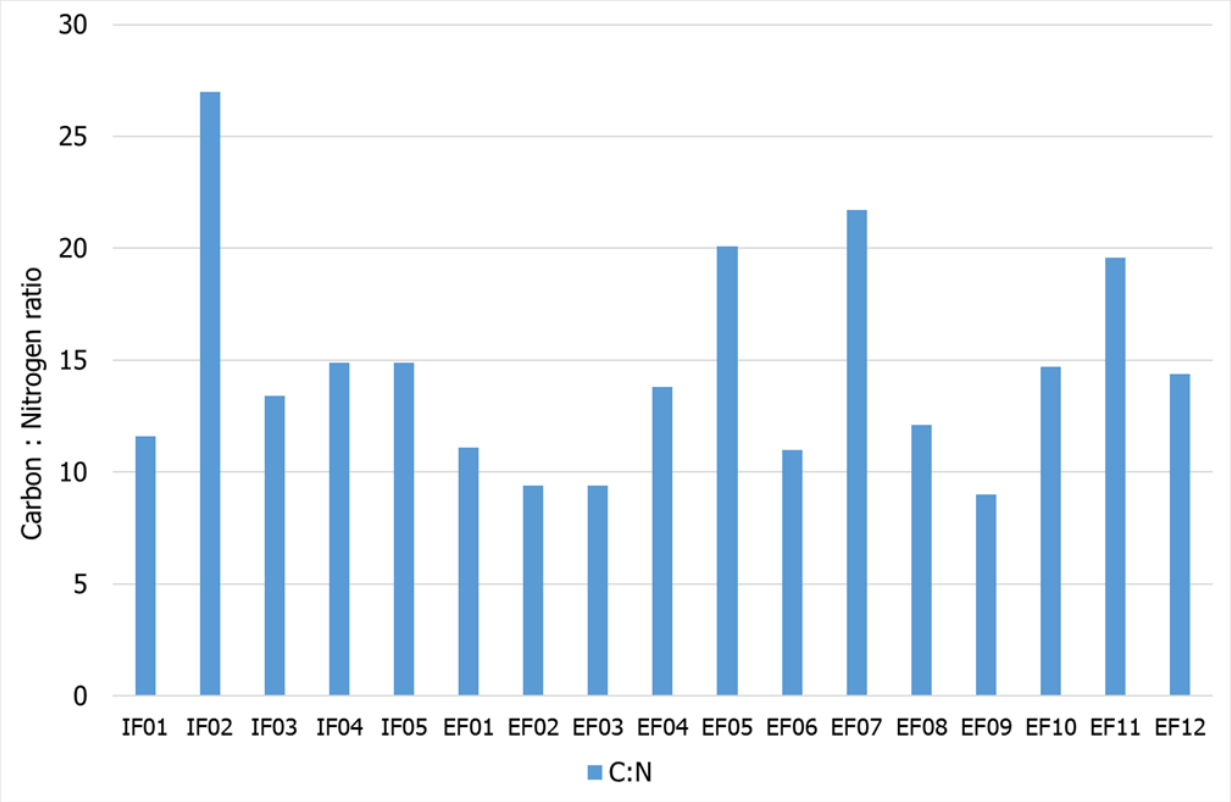

Figure 5.7: C:N for Hawke's Bay Forest Sites Sampled in 2015

5.3.8 Bulk Density

Figure 5.8 shows the bulk density results for forest sites. Three sites had measured bulk density at or below the lower target range limit of 0.7 – 1.4 g/cm^3 for Pallic soils and 0.6 – 1.4 g/cm^3 for Pumice and Brown soils. Fourteen sites were within the target range for bulk density. Low bulk density at exotic forest sites is likely due to soil disturbance by forestry operations. Low bulk density can also be the result of erosion on slopes, root exploration by trees and organic matter accumulation. Furthermore, pumice soils generally have low bulk densities and were present at a number of sites. Low measured bulk density may increase the risk of soil movement on sloping sites, but should not cause limitations to forest growth.

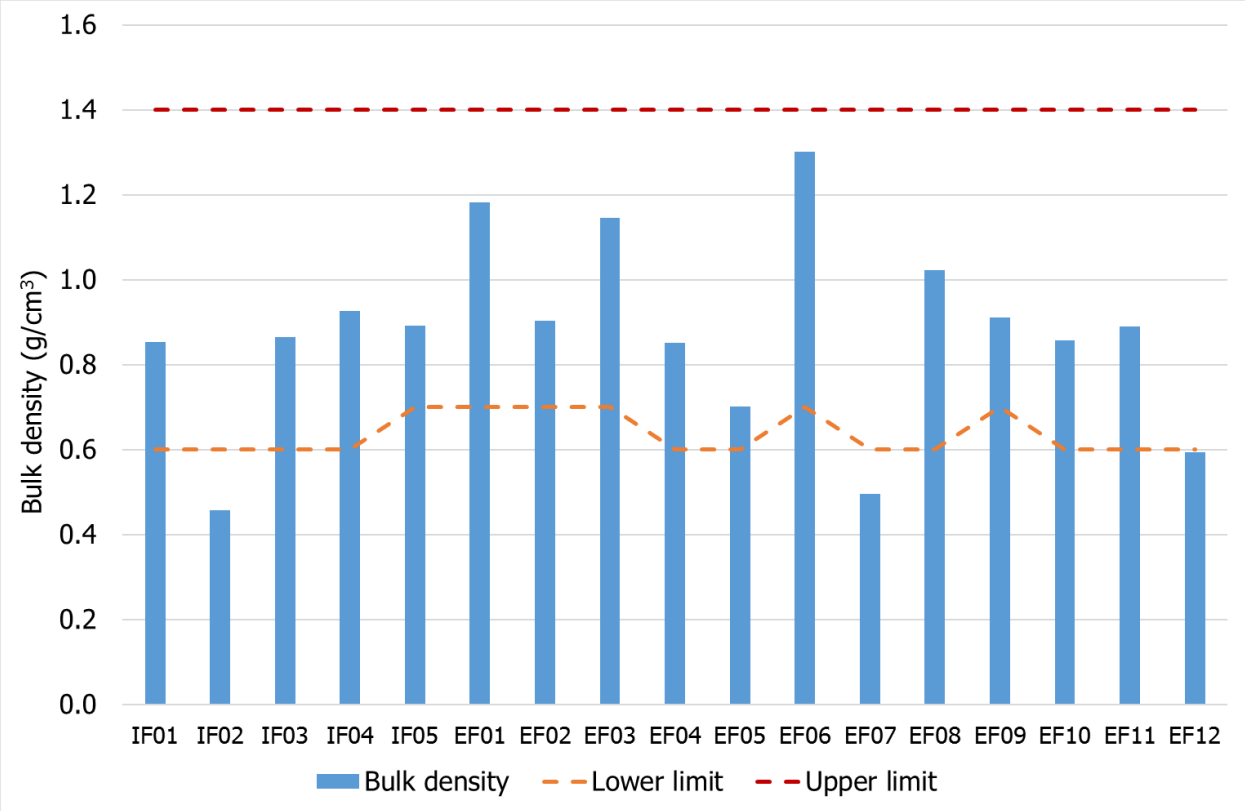

Figure 5.8: Bulk density for Hawke's Bay Forest Sites Sampled in 2015

5.3.9 Macroporosity

Figure 5.9 shows the macroporosity results for the forest sites. None of the sites had a measured macroporosity below the target range of 8% but six sites had measured macroporosity above the target range of 30%. High macroporosity at forest sites is likely a result of root exploration, incorporation of organic matter from leaf litter and potential mass movement on the typically sloping sites. Site IF02 was noted to be dominated by pumice soil, leading to a high proportion of macropores.

EF02 was located close to areas that showed mass movement and this may have influenced the macroporosity measured at this site. EF05 was located near an area which appeared to have redeposited spoil (possibly from track maintenance) which may result in higher macroporosity. Site EF07 was located in a block which showed signs of animal disturbance and historically had been subject to fire damage and subsequent windthrow of trees. In addition, the pumiceous nature of the soil is expected to have contributed to high macroporosity. High macroporosity at EF10 is also likely a result of the pumiceous nature of the soil. Thesandy soil texture and nearby gullying is reflected in the high macroporosity at Site EF12.

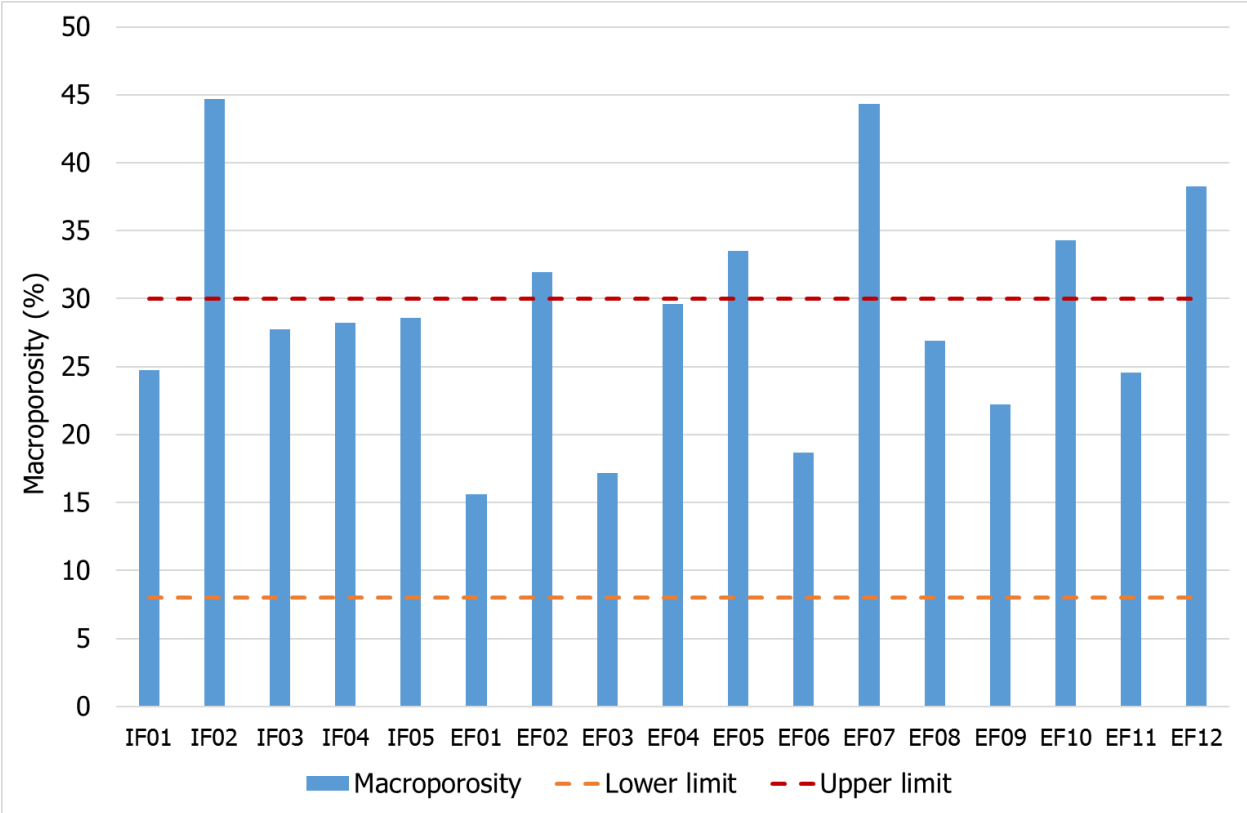

Figure 5.9: Macroporosity for Hawke's Bay Forest Sites Sampled in 2015

5.4 Priority Two Indicators

Priority Two indicators were not determined for this sampling round.

5.5 Priority Three Indicators

The results from the soils analysed are described as follows.

5.5.1 Organochlorine Pesticides

Only one site (EF12) recorded a detectable result for measured organochlorine pesticides. Of the measured organochlorine pesticides, only DDT or its metabolites (DDD, DDE) were detected at EF12. In the absence of a New Zealand guideline for the protection of soil health, the measured values were compared to the Canadian Council of Ministers of the Environment (CCME, 1999) guideline. The CCME guideline for soil quality for protection of environmental and human health is 0.7 mg/kg ΣDDT+DDE+DDD. The recorded value at EF12 was 0.07 mg/kg ΣDDT+DDE+DDD, which is ten times below the limit.

5.5.2 Trace Elements

Measured levels of trace elements are well below levels corresponding to risk to environmental or human health for all sites (NZWWA & MfE, 2003).

Section 3.4 above indicates the potential for elevated Cd levels where superphosphate has beenapplied. No recorded values for Cd were above the guideline limit and this is reflected in the P status as well as the measured F and U values, which all indicate there is not significant accumulation of fertiliser contaminants in the forest soils.

5.5.3 Fluoride (F^-)

Measured F^- values varied from 132 mg/kg to 280 mg/kg. None of the forest sites sampled had F^- results above the expected range for NZ soils (200 - 500 mg/kg, FLRC, 2009).

As with P, Cd and U results, high F concentrations may reflect phosphate fertiliser addition. Another potential source of F is from volcanic ash which has showered Hawke's Bay in the past.

5.5.4 Uranium (U)

Measured U varied from 0.28 mg/kg to 0.86 mg/kg. In general, levels are low and below the proposed Canadian soil limit of 23 mg/kg (CCME, 1999). However, further information is required to determine a New Zealand limit (Taylor, 2007).

5.6 Overall Soil Quality

The results from the soils analysed have been compared to the interpretative Framework which categorises the results against target ranges and/or critical limits.

One site meets all soil quality targets, 11 met all but one target, 2 sites had two targets unmet, 2 sites had three targets unmet and a single site had four targets unmet. Figure 11 shows the proportion of targets that were met by each site.

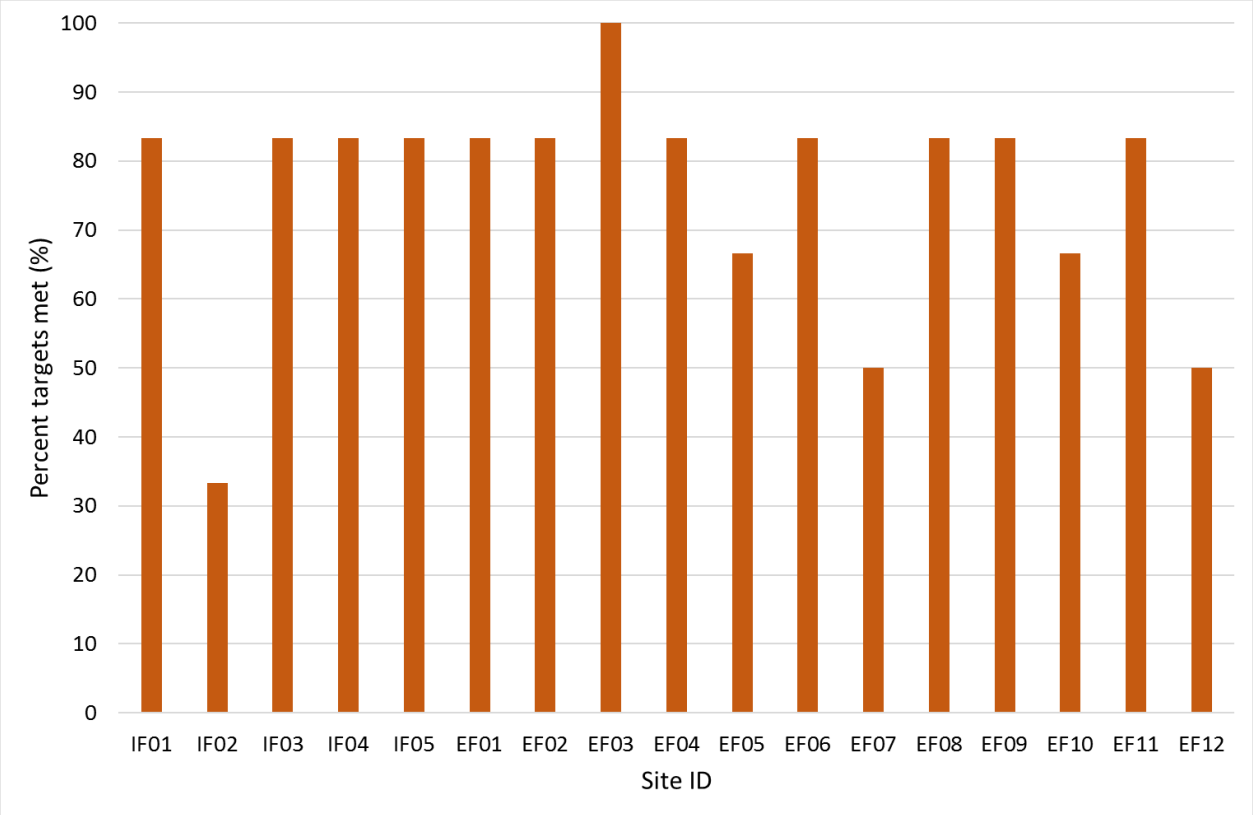

Figure 11: Proportion of soil quality targets met for Hawke's Bay forest sites sampled in 2015

Soil quality indicators for which a target was not met were:

- Exceeded anaerobically mineralisable nitrogen target range (IF02);
- Below Olsen P target range (IF01, IF02, IF03, IF04, IF05, EF01, EF04, EF05, EF06, EF07, EF08, EF09, EF10, EF11, EF12);
- Below bulk density target range (IF02, EF07, EF12); and

- Exceeded macroporosity target range (IF02, EF02, EF05, EF07, EF10, EF12).

Where targets were not met, it reflected the use of marginal land for forestry land use, i.e. steep slopes and low natural fertility, and the accumulation of organic matter under long term forested sites. IF02 had the highest number of targets not met which may reflect the combination of high altitude leading to slow growth and nutrient cycling, steep slopes leading to low accumulation of mineral soil and minimal management inputs.

In general, the measured soil quality is not expected to cause limitations to the current land use of the sites.

5.7 Changes in Soil Quality Over Time

The 2015 sampling round represents the first forest sites in the soil quality monitoring programme. At this stage, no evaluation of changes in soil quality indicators over time can be made.

6 DISCUSSION

Soil quality of forest sites has not been previously measured in Hawke's Bay region. In general, most soil quality indicators are met for the majority of sites, suggesting that the quality of forest soils is acceptable. Issues predominantly relate to soil porosity and Olsen P, and these are discussed below.

Indigenous forest is a low to nil management input land use and as a result, soil quality tends to represent the natural fertility of a site, and the long-term lack of soil disturbance. Olsen P was the most limiting parameter for indigenous forest sites with recycling of P from leaf litter likely to be the main source of P in these areas. The plant assemblage is expected to be adapted to the phosphorus levels available and although low, P is not considered to be limiting to the indigenous forest.

Phosphorus in exotic forest soils is expected to stabilise at canopy closure, with tree crop needs being met by natural nutrient cycling from within the ecosystem. Low P is not considered to be limiting to the exotic forest land use.

Forest sites were predominantly on steep and rolling hill country, which is prone to mass movement. This likely results in higher macroporosity and lower bulk density due to gaps created by moving soil. Generally, forest cover reduces the incidence of mass movement as roots from trees and shrubs anchor the soil. Some shallow slippage may occur at higher rates compared to grazed pasture where compaction by animals reduces soil movement. However, on long-term forest sites, this is considered to be a minor consideration. High macroporosity also occurs on forest sites due to larger roots of trees and shrubs (compared to pasture species), creating a higher macropore volume and this may also lead to lower bulk density values.

A relatively stable organic matter pool is expected under indigenous forest, and the measured soil quality reflects this. Under exotic forest, a high degree of disturbance occurs at harvest and cultivation which may significantly reduce the organic matter in the soil. The aim of assessing sites following canopy closure is to avoid measurement of short-term effects due to harvest and cultivation.

Sources of contamination in indigenous forests are limited to pest control measures (pesticides). In exotic forests, pest control, weed management and tree fungicides are potential sources of contamination. Contaminant levels on the forest soils were low to undetectable, and no further investigation is needed at this time. Low contaminant levels reflect low management inputs for the forestry land use.

For the sites evaluated, the measured soil quality parameters do not indicate a limitation to the current forestry land use.

7 CONCLUSIONS

- In general, soil quality in Hawke's Bay indigenous and exotic forest sites is suitable for the current forestry land use;
- Soil fertility is expected to be low, reflecting the nutrient cycling that occurs in forests following canopy closure. As a result, low Olsen P is not considered to be limiting to the current land use;
- Soil physical condition reflects the dominant land forms (steep and rolling slopes) and vegetation, resulting in high macroporosity and low bulk density on a number of sites; and
- Low fertility and the soil physical condition are suitable for the forestry land use.

8 RECOMMENDATIONS

- Managers of the properties sampled should be informed of the soil quality on their properties. No remedial activity is recommended for any site in this sampling round; and
- The same sites should be resampled within five years and at ongoing intervals to develop a long-term record of soil quality indicator performance over time.

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10APPENDICES

Appendix A Soil Descriptions
Appendix B Laboratory Analysis Reports

APPENDIX A

Soil Descriptions

Appendix A: Soil Descriptions – Indigenous and Exotic Forest

IF01

Soil	Matamau
	Silt loam
Transect length and direction	50 m
Classification	Typic Orthic Brown
Land use	Indigenous forest
Date sampled	30/11/2015
Land use history	Indigenous forest
Present vegetation	Lowland podocarp forest
Slope degrees	7-15
Landform	Low rolling hills
Annual rain (mm)	1,000
Elevation (m)	280-300
Parent material	Greywacke alluvium and loess
Drainage	Well drained
Topsoil depth (cm)	15
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
F	0 - 15	Very dark greyish brown (10YR 3/2) humic litter; profuse roots; weak soil strength; indistinct wavy boundary; slightly moist
Ah	15 - 25	Dark brown (10YR 3/3) silt loam; non sticky; slightly plastic; weakly pedal; fine polyhedral peds; slightly firm soil strength; common fine roots; diffuse irregular boundary; dry
Bw	25 - 65	Dark yellowish brown (10YR 4/4) silt loam; few fine (dark orange) mottles; non sticky; slightly plastic; apedal earthy; few fine roots; indistinct smooth boundary; dry.
Bw2	65 - 80+	Yellowish brown (10YR 5/6) slightly gravelly sandy loam; weathered sub-rounded greywacke; apedal earthy; dry

IF02

Soil	Ruahine
	Sandy loam
Transect length and direction	50 m
Classification	Typic Orthic Brown
Land use	Indigenous forest
Date sampled	30/11/2015
Land use history	Indigenous forest
Present vegetation	Mountain beech
Slope degrees	15-25˚
Landform	Steep hill country, concave top slope
Annual rain (mm)	1,800
Elevation (m)	
Parent material	In-situ and colluvial greywacke
Drainage	Well
Topsoil depth (cm)	14
Limiting horizon	Fractured to unaltered rock
Sampled by	KB/KH

Horizon	Depth (cm)	Description
F	0 - 14	Black (10YR 2/1) mesic humic litter; many fine roots; distinct wavy boundary; slightly moist.
Af	14 - 44	Dark yellowish brown (10YR 3/4) slightly gravelly sandy loam; apedal earthy; common fine and medium roots; indistinct wavy boundary; slightly moist.
Bw	44 - 62	Dark yellowish brown (10YR 4/4) moderately gravelly loamy sand; apedal earthy; common fine and medium roots; indistinct smooth boundary; slightly moist.
C	62 - 74+	Coarse sub-angular gravel; slightly moist.

IF03

Soil	Kaweka sandy loam
Transect length and direction	50 m
Classification	Typic Orthic Pumice
Land use	Indigenous forest
Date sampled	30/11/2015
Land use history	Indigenous forest
Present vegetation	Mountain beech
Slope degrees	15-25˚
Landform	Rolling hill, convex top slope
Annual rain (mm)	1,800
Elevation (m)	
Parent material	Ash over greywacke
Drainage	Well
Topsoil depth (cm)	Litter over B horizon
Limiting horizon	Unaltered greywacke
Sampled by	KH/KB

Horizon	Depth (cm)	Description
F	0 - 5	Very dusky red (2.5YR 2.5/2) very slightly gravelly mesic litter; apedal earthy; weak soil strength; many fine roots; distinct wavy boundary; slightly moist.
Bw	5 - 70+	Dark yellowish brown (10YR 4/4) very slightly gravelly sandy loam; apedal earthy; weak soil strength; common medium roots; slightly moist.

IF04

Soil	Gisborne
	Sandy loam
Transect length and direction	50 m
Classification	Typic Orthic Pumice
Land use	Indigenous forest
Date sampled	7/12/2015
Land use history	Indigenous forest
Present vegetation	Nikau, tawa, kohekohe
Slope degrees	20-25
Landform	Steep concave midslope
Annual rain (mm)	2,000
Elevation (m)	
Parent material	Ash, fine pumice lapilli
Drainage	Well
Topsoil depth (cm)	15
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ah	0 - 10	Very dark grey (10YR 3/1) silt loam; non-sticky; slightly plastic; apedal earthy; abundant fine and medium roots; distinct smooth boundary; slightly moist.
Bw	10 - 23	Brown (10YR 4/3) silt loam; non-sticky; slightly plastic; apedal earthy; soil strength; few fine and medium roots; diffuse smooth boundary; slightly moist.
Bw2	23 - 44	Yellowish brown (10YR 5/6) silt loam; few coarse (iron stain) mottles; non-sticky; slightly plastic; apedal earthy; few fine and medium roots; diffuse smooth boundary; slightly moist.
Bw3	44 - 85	Yellowish brown (10YR 5/4) silt loam; common coarse (iron stain) mottles; non-sticky; slightly plastic; apedal earthy; few coarse roots; diffuse smooth boundary; slightly moist.
BC	85 - 100+	Light yellowish brown (10YR 6/4) loamy sand; many coarse (iron stain) mottles; non-sticky; non-plastic; apedal earthy; few coarse roots; slightly moist.

IF05

Soil	Mahoenui
	Sandy silt loam
Transect length and direction	50 m
Classification	Pallic
Land use	Indigenous forest
Date sampled	7/12/2015
Land use history	Indigenous forest
Present vegetation	Tawa, nikau, kohekohe
Slope degrees	20-25
Landform	Steep hills, concave upper slope
Annual rain (mm)	2,000
Elevation (m)	
Parent material	Loess and tephric loess over mudstone
Drainage	Imperfect
Topsoil depth (cm)	10
Limiting horizon	Mudstone
Sampled by	KH/KB

Horizon	Depth (cm)	Description
F	0 - 14	Black (7.5YR 2.5/1) litter; non-sticky; non-plastic; apedal earthy; abundant medium and coarse roots; diffuse smooth boundary; dry.
Ah	14 - 25	Dark yellowish brown (10YR 4/4) sandy silt loam; non-sticky; non-plastic; apedal earthy; common medium and coarse roots; indistinct smooth boundary; slightly moist.
Bw	25 - 40	Yellowish brown (10YR 5/4) silt loam; few coarse (iron stain) mottles; non-sticky; non-plastic; apedal massive breaking to blocky; few medium and coarse roots; indistinct smooth boundary; slightly moist.
Bt	40 - 55	Brown (10YR 5/3) silt loam; common coarse (iron stain) mottles; non-sticky; non-plastic; apedal massive breaking to blocky; few medium and coarse roots; indistinct smooth boundary; slightly moist.
BC	55 - 100+	Brown (10YR 5/3) weathered papa; common coarse (iron stain) mottles; slightly sticky; slightly plastic; apedal massive breaking to blocky; few medium roots; moist.

EF01

Soil	Crownthorpe
	Silt loam
Transect length and direction	50 m
Classification	Pallic
Land use	Exotic forest
Date sampled	29/11/2015
Land use history	Extensive pasture converted to forest
Present vegetation	Pinus Radiata (20 yo), pasture understorey
Slope degrees	15-25
Landform	Steep slopes, planar to convex upper mid-slope
Annual rain (mm)	1,500
Elevation (m)	
Parent material	Loess over greywacke alluvium (uplifted)
Drainage	Moderate
Topsoil depth (cm)	25
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 12	Very dark greyish brown (10YR 3/2) very slightly gravelly silt loam; non-sticky; non-plastic; apedal earthy; common fine and medium roots; indistinct wavy boundary; slightly moist.
Ap2	12 - 25	Very dark grey (10YR 3/1) slightly gravelly silt loam; non-sticky; non-plastic; apedal earthy; few fine and medium roots; distinct occluded boundary; slightly moist.
Bw	25 - 41	Light olive brown (2.5Y 5/3) slightly gravelly sandy loam; non-sticky; non-plastic; apedal earthy; few fine and medium roots; indistinct wavy boundary; moist.
B2	41 - 60	Light olive brown (2.5Y 5/4) moderately gravelly loamy sand; non-sticky; non-plastic; apedal earthy; many fine and medium roots; indistinct wavy boundary; moist.
B3	60 - 70+	Pale olive (5Y 6/3) moderately gravelly clayey silt; moderately sticky; very plastic; apedal massive; very few fine roots; moist.

EF02

Soil	Te Apiti
	Clay loam
Transect length and direction	50 m
Classification	Pallic
Land use	Exotic forest
Date sampled	29/11/2015
Land use history	Extensive pasture converted to forest
Present vegetation	Pinus Radiata (15 yo)
Slope degrees	15-25
Landform	Steep slopes, planar to concave upper mid-slope
Annual rain (mm)	1,500
Elevation (m)	
Parent material	Loess over argillite
Drainage	Imperfect
Topsoil depth (cm)	25
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
F	0 - 5	Black (7.5YR 2.5/1) mesic litter; non-sticky; non-plastic; apedal earthy; indistinct wavy boundary; slightly moist.
Ap	5 - 30	Black (2.5Y 2.5/1) moderately gravelly clay loam; very sticky; very plastic; apedal earthy; soil strength; many fine roots; distinct wavy boundary; slightly moist.
B	30 - 44	Light olive brown (2.5Y 5/4) moderately gravelly clay; moderately sticky; moderately plastic; apedal earthy; soil strength; common fine roots; indistinct wavy boundary; slightly moist.
B	44 - 150+	Light yellowish brown (2.5Y 6/4) loamy gravel; few coarse (iron stain) mottles; apedal earthy; soil strength; few fine and medium roots; slightly moist.

EF03

Soil	Waipawa
	Clay loam
Transect length and direction	50 m
Classification	Pallic
Land use	Exotic forest
Date sampled	29/11/2015
Land use history	Extensive pasture converted to forest
Present vegetation	Pinus Radiata (5 yo)
Slope degrees	15-20
Landform	Rolling hills
Annual rain (mm)	900
Elevation (m)	
Parent material	Loess over argillite
Drainage	Moderate
Topsoil depth (cm)	20
Limiting horizon	Pan
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 20	Very dark greyish brown (10YR 3/2) clay loam; moderately sticky; very plastic; moderately pedal; medium polyhedral peds; weak soil strength; few fine roots; indistinct smooth boundary; dry.
B	20 - 40	Yellowish brown (10YR 5/4) very slightly gravelly silty clay; very sticky; moderately plastic; weakly pedal; coarse blocky peds; weak soil strength; few fine roots; indistinct smooth boundary; dry.
B	40 - 60+	Yellowish brown (10YR 5/4) slightly gravelly silty clay; very sticky; moderately plastic; weakly pedal; coarse blocky peds; weak soil strength; dry.

EF04

Soil	Gvawas
	Silt loam
Transect length and direction	50 m
Classification	Typic Orthic Brown
Land use	Exotic forest
Date sampled	2/12/2015
Land use history	Multiple rotation exotic forest
Present vegetation	Pinus Radiata (15 yo), blackberry understorey
Slope degrees	15-20
Landform	Rolling hills
Annual rain (mm)	1,600
Elevation (m)	
Parent material	Greywacke
Drainage	Well
Topsoil depth (cm)	30
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ah	0 - 30	Reddish black (2.5YR 2.5/1) silt loam; apedal earthy; weak soil strength; common fine and medium roots; diffuse wavy boundary; dry.
Bw	30 - 52	Dark yellowish brown (10YR 3/4) very slightly gravelly sandy silt loam; apedal earthy; weak soil strength; common fine and medium roots; distinct wavy boundary; dry.
BC	52 - 80+	Yellowish brown (10YR 5/8) moderately gravelly sandy loam; apedal earthy; weak soil strength; few fine and medium roots; dry.

EF05

Soil	Ruahine (disturbed)
	Sandy loam
Transect length and direction	50 m
Classification	Typic Orthic Brown
Land use	Exotic forest
Date sampled	2/12/2015
Land use history	Multiple rotation exotic forest
Present vegetation	Pinus radiata, understorey coprosma, fern, bracken, leaf litter etc.
Slope degrees	20-25
Landform	Steep hills, concave top slope
Annual rain (mm)	1,600
Elevation (m)	
Parent material	Ash over greywacke
Drainage	Moderate
Topsoil depth (cm)	17
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 17	Very dark grey (10YR 3/1) very slightly gravelly sandy loam; apedal earthy; weak soil strength; common fine and medium roots; distinct occluded boundary; dry.
B	17 - 28	Dark yellowish brown (10YR 4/4) clay loam; apedal earthy; peds; weak soil strength; few fine and medium roots; indistinct occluded boundary; dry.
bAp	28 - 42	Very dark grey (10YR 3/1) sandy loam; moderately sticky; moderately plastic; apedal earthy; weak soil strength; many fine and medium roots; distinct smooth boundary; dry.
Bw	42 - 100+	Dark yellowish brown (10YR 4/4) clay loam; moderately sticky; moderately plastic; apedal earthy; weak soil strength; few fine and medium roots; dry.

EF06

Soil	Te Apiti
	Silt loam
Transect length and direction	50 m
Classification	Pallic
Land use	Exotic forest
Date sampled	2/12/2015
Land use history	Exotic forest
Present vegetation	Pinus Radiata (20 yo)
Slope degrees	20-25
Landform	Steep hills, convex midslope
Annual rain (mm)	1,200
Elevation (m)	
Parent material	Loess over argillite
Drainage	Poor
Topsoil depth (cm)	10
Limiting horizon	Pan
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 10	Very dark grey (5YR 3/1) silt loam; non-sticky; slightly plastic; weakly pedal; fine polyhedral peds; weak soil strength; common fine and medium roots; distinct wavy boundary; slightly moist.
Bw	10 - 38	Pale yellow (2.5Y 7/3) sandy loam; few fine (bright orange) mottles; non-sticky; slightly plastic; weakly pedal; fine polyhedral peds; slightly firm soil strength; few medium roots; distinct wavy boundary; slightly moist.
Btg	38 - 65	Light yellowish brown (2.5Y 6/4) clayey silt loam; many fine (bright orange) mottles; slightly sticky; moderately plastic; apedal massive; very firm soil strength; few medium roots; indistinct wavy boundary; slightly moist.
Bt	65 - 78+	Light yellowish brown (2.5Y 6/3) clay loam; common fine (dark orange) mottles; moderately sticky; very plastic; weakly pedal; coarse blocky peds; firm soil strength; slightly moist.

EF07

Soil	Tuai (disturbed)
	Sandy loam
Transect length and direction	50 m
Classification	Pumice
Land use	Exotic forest
Date sampled	3/12/2015
Land use history	Multiple rotation exotic forest
Present vegetation	Pinus Radiata (20 yo)
Slope degrees	15
Landform	Rolling to steep hills, upper mid slope
Annual rain (mm)	1,300
Elevation (m)	
Parent material	Airfall tephra (pumice)
Drainage	Well to excessive
Topsoil depth (cm)	15
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 15	Black (10YR 2/1) slightly gravelly sandy loam; non-sticky; non-plastic; apedal earthy; weak soil strength; few fine and medium roots; indistinct occluded boundary; slightly moist.
BW	15 - 60	Brown (10YR 4/3) slightly gravelly sandy loam; non-sticky; non-plastic; apedal earthy; weak soil strength; few fine and medium roots; distinct wavy boundary; slightly moist.
BC	60 - 100+	Dark yellowish brown (10YR 4/4) moderately gravelly sand; non-sticky; non-plastic; apedal single grain; weak soil strength; common fine roots; slightly moist.

EF08

Soil	Hangaroa
	Silt loam
Transect length and direction	50 m
Classification	Pumice
Land use	Exotic forest
Date sampled	3/12/2015
Land use history	Exotic forest
Present vegetation	Pinus radiata, understorey grass, blackberry and fern
Slope degrees	25
Landform	Steep hills
Annual rain (mm)	1,400
Elevation (m)	
Parent material	Tephric loess over argillite
Drainage	Poor
Topsoil depth (cm)	20
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 20	Very dark greyish brown (10YR 3/2) silt loam; non-sticky; non-plastic; weakly pedal; fine polyhedral peds; weak soil strength; common fine roots; distinct wavy boundary; slightly moist.
Bw	20 - 37	Light yellowish brown (10YR 6/4) sandy silt loam; few medium (orange) mottles; non-sticky; non-plastic; weakly pedal; fine polyhedral peds; weak soil strength; few medium roots; distinct wavy boundary; slightly moist.
Bt	37 - 80+	Light yellowish brown (2.5Y 6/4) clay loam; many medium (dark orange) mottles; very sticky; very plastic; weakly pedal; fine polyhedral peds; weak soil strength; few medium roots; slightly moist.

EF09

Soil	Mahoenui
	Silt loam
Transect length and direction	50 m
Classification	Pallic
Land use	Exotic forest
Date sampled	3/12/2015
Land use history	Extensive pasture converted to forest
Present vegetation	Pinus radiata, understorey grass, blackberry, digitalis, litter, fern
Slope degrees	15-20
Landform	Rolling hills
Annual rain (mm)	1,400
Elevation (m)	
Parent material	Loess over argillite and sandstone
Drainage	Imperfect
Topsoil depth (cm)	8
Limiting horizon	Pan
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 8	Black (10YR 2/1) silt loam; slightly sticky; slightly plastic; apedal earthy; peds; weak soil strength; few fine and medium roots; diffuse smooth boundary; slightly moist.
Bw	8 - 22	Dark yellowish brown (10YR 4/4) sandy loam; non-sticky; non-plastic; apedal earthy; weak soil strength; few medium roots; diffuse smooth boundary; slightly moist.
Bt	22 - 60	Light yellowish brown (2.5Y 6/3) silt loam; many fine (dark orange) mottles; slightly sticky; slightly plastic; weakly pedal; blocky breaking to fine polyhedral peds; firm soil strength; few medium roots; indistinct wavy boundary; slightly moist.
Bt	60 - 80+	Light yellowish brown (2.5Y 6/3) silty clay; abundant fine (dark orange) mottles; moderately sticky; very plastic; weakly pedal; blocky breaking to fine polyhedral peds; firm soil strength; slightly moist.

EF10

Soil	Taupo/Kaweka integrade
	Sandy loam
Transect length and direction	50 m
Classification	Typic Orthic Pumice
Land use	Exotic forest
Date sampled	4/12/2015
Land use history	Multiple rotation exotic forest
Present vegetation	Pinus Radiata (12 yo)
Slope degrees	20-25
Landform	Steep hills
Annual rain (mm)	1,200
Elevation (m)	
Parent material	Airfall tephra (pumice)
Drainage	Well
Topsoil depth (cm)	24
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 24	Black (10YR 2/1) sandy loam; non-sticky; non-plastic; apedal earthy; weak soil strength; common fine roots; indistinct wavy boundary; dry.
Bw	24 - 32	Dark greyish brown (10YR 4/2) very slightly gravelly loamy sand; non-sticky; non-plastic; apedal earthy; weak soil strength; common fine roots; diffuse occluded boundary; slightly moist.
BC	32 - 55	Yellowish brown (10YR 5/6) very slightly gravelly coarse pumice sand and heavy minerals; non-sticky; non-plastic; apedal single grain; weak soil strength; few medium roots; indistinct wavy boundary; slightly moist.
BC	55 - 75	Dark brown (10YR 3/3) very slightly gravelly medium to coarse sand; non-sticky; non-plastic; apedal single grain; weak soil strength; few fine roots; indistinct wavy boundary; slightly moist.
BC	75 - 90+	Light yellowish brown (2.5Y 6/4) very slightly gravelly fine sand; few fine (dark orange) mottles; non-sticky; non-plastic; apedal single grain; weak soil strength; few fine roots; slightly moist.

EF11

Soil	Taupo (disturbed)
	Sandy loam
Transect length and direction	50 m
Classification	Immature Orthic Pumice
Land use	Exotic forest
Date sampled	4/12/2015
Land use history	Multiple rotation exotic forst
Present vegetation	Pinus Radiata (15 yo)
Slope degrees	3-5
Landform	Low rolling hills
Annual rain (mm)	1,200
Elevation (m)	
Parent material	Airfall tephra (pumice)
Drainage	Moderate
Topsoil depth (cm)	20
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 20	Very dark greyish brown (10YR 3/2) sandy loam; non-sticky; non-plastic; apedal earthy; weak soil strength; common fine roots; distinct wavy boundary; dry.
Bw	20 - 24	Brown (10YR 4/3) loamy sand; non-sticky; non-plastic; apedal massive breaking to fine polyhedral; weak soil strength; few fine roots; indistinct irregular boundary; slightly moist.
Bw2	24 - 28	Dark yellowish brown (10YR 4/4) loamy sand; non-sticky; non-plastic; apedal massive breaking to fine polyhedral; weak soil strength; few fine and medium roots; distinct smooth boundary; slightly moist.
Bw3	28 - 50	Light olive brown (2.5Y 5/3) loamy sand; few medium (dark orange) mottles; non-sticky; non-plastic; apedal massive breaking to fine polyhedral peds; weak soil strength; few fine and medium roots; distinct wavy boundary; slightly moist.
Bw4	50 - 70	Dark yellowish brown (10YR 4/6) loamy sand; abundant medium (dark orange) mottles; non-sticky; non-plastic; apedal massive breaking to fine polyhedral peds; weak soil strength; few fine roots; indistinct wavy boundary; slightly moist.
	70 - 80+	Loamy sand soil and slash; common medium (dark orange) mottles; non-sticky; non-plastic; apedal massive breaking to fine polyhedral peds; weak soil strength; slightly moist.

EF12

Soil	Gisborne
	Sandy loam
Transect length and direction	50 m
Classification	Typic Orthic Pumice
Land use	Exotic forest
Date sampled	4/12/2015
Land use history	Multiple rotation exotic forest
Present vegetation	Pinus Radiata (20 yo)
Slope degrees	7-15
Landform	Low rolling hills
Annual rain (mm)	1,200
Elevation (m)	
Parent material	Airfall tephra (pumice)
Drainage	Well to excessive
Topsoil depth (cm)	34
Limiting horizon	None
Sampled by	KH/KB

Horizon	Depth (cm)	Description
Ap	0 - 34	Very dark greyish brown (10YR 3/2) sandy loam with occasional pumice clasts; non-sticky; non-plastic; apedal earthy; weak soil strength; common fine roots; distinct wavy boundary; slightly moist.
Bw	34 - 80+	Brown (10YR 4/3) sandy loam with occasional pumice clasts; non-sticky; non-plastic; apedal earthy; weak soil strength; few medium roots; dry.

APPENDIX B

Laboratory Analysis Reports

Soil Physics Laboratory
Analytical Report

Landcare Research
Manaaki Whenua

Private Bag 11052
Palmerston North 4442

phone: +64 6 353 4911
fax: +64 6 353 4801

Job Number: PJ15021

Date Received: 20/01/2016

Customer: Hawke's Bay Regional Council
Keiko Hashiba

Date Reported: 04/03/2016

Core No.	Site name	Comments	Sample ID	Particle density (g/cm^3)	Dry bulk density (g/cm^3)	Porosity (%)	Macro-porosity (%)	Air capacity (%)	Field capacity (%)	AWC (%)
906	EF01a		PP15-0621	2.51	1.17	53	12	14	39	23
940	EF01b		PP15-0622	2.47	1.11	55	14	18	37	21
996	EF01c		PP15-0623	2.52	1.27	50	11	14	35	16
918	EF02a		PP15-0624	2.39	0.87	63	19	26	37	21
794	EF02b	Hydrophobic. 80% wet up after 7 days wetting.	PP15-0625	2.46	1.01	59	32	34	24	6
975	EF02c	Hydrophobic. 60% wet up after 7 days wetting.	PP15-0626	1.76	0.83	53	34	36	18	5
731	EF03a	V. dry. Hydrophobic. 90% wet up after 7 days.	PP15-0627	2.45	1.10	55	16	18	37	16
833	EF03b	V. dry	PP15-0628	2.56	1.19	53	15	18	36	8
955	EF03c	V. dry. Hydrophobic. 90% wet up after 7 days.	PP15-0629	2.49	1.15	54	15	16	38	12
738	IF01a		PP15-0630	2.45	0.67	72	26	30	42	23
841	IF01b		PP15-0631	2.56	1.06	58	19	22	36	18
929	IF01c		PP15-0632	2.56	0.82	68	20	21	47	17
703	IF02a		PP15-0633	2.33	0.40	83	39	50	33	20
909	IF02a		PP15-0634	2.40	0.46	81	39	47	34	16
990	IF02a		PP15-0635	2.31	0.52	78	32	37	40	19
825	IF03a		PP15-0636	2.52	0.79	69	15	18	51	29
911	IF03b	Many stones 2 - 10 mm	PP15-0637	2.56	1.09	58	22	26	32	11
988	IF03c	A few stones	PP15-0638	2.40	0.72	70	33	39	31	8
818	EF05a	A few stones	PP15-0639	2.42	0.62	74	33	38	37	13
977	EF05b		PP15-0640	2.52	0.62	75	27	32	43	14

993	EF05c	5% pine bark. A few stones	PP15-0641	2.50	0.86	66	28	31	35	9
806	EF04a		PP15-0642	2.44	0.87	64	24	27	37	16
878	EF04b	A few stones	PP15-0643	2.44	0.89	64	25	30	33	9
927	EF04c	Hydrophobic. 90% wet up after 7 days wetting.	PP15-0644	2.45	0.80	67	28	31	36	14
734	EF06a		PP15-0645	2.53	1.19	53	14	20	33	19
821	EF06b		PP15-0646	2.61	1.38	47	13	16	31	19
961	EF06c		PP15-0647	2.67	1.33	50	17	20	30	15
835	EF07a	10% cavity filled	PP15-0648	2.31	0.54	77	35	41	35	21
867	EF07b		PP15-0649	2.28	0.56	75	33	40	35	26
964	EF07c		PP15-0650	2.15	0.39	82	46	51	31	19
986	EF08a		PP15-0651	2.35	0.75	68	25	32	36	24
755	EF08b		PP15-0652	2.47	0.97	60	25	30	30	20
788	EF08c		PP15-0653	2.64	1.35	49	15	18	31	17
837	EF09a	2 15mm dia. X 8 cm roots	PP15-0654	2.49	0.84	66	24	26	40	19
926	EF09b		PP15-0655	2.44	0.90	63	23	26	37	20
863	EF09c		PP15-0656	2.56	1.00	61	12	14	47	23
760	EF12a		PP15-0657	2.29	0.56	76	30	38	38	22
874	EF12b		PP15-0658	2.35	0.60	75	31	40	35	20
946	EF12c		PP15-0659	2.29	0.62	73	32	37	35	23
742	EF11a	95% consolidated pumice sand	PP15-0660	2.57	1.24	52	12	14	38	12
780	EF11b		PP15-0661	2.40	0.70	71	29	35	36	17
956	EF11c		PP15-0662	2.25	0.72	68	22	26	42	27
923	EF10a	A few stones	PP15-0663	2.30	1.01	56	27	31	26	7
995	EF10b		PP15-0664	2.28	0.64	72	32	37	35	21
706	EF10c		PP15-0665	2.50	0.92	63	33	36	27	14
747	IF05a	25% consolidated pumice sand	PP15-0666	2.62	1.08	59	23	26	33	15
762	IF05b	sample thick with roots. Most removed successfully.	PP15-0667	2.53	0.60	76	38	40	36	20
844	IF05c	sample thick with roots. Most removed successfully. 10% consolidated pumice sand	PP15-0668	2.56	0.99	61	18	20	42	25
839	IF04a		PP15-0669	2.57	0.86	66	29	32	34	17
932	IF04b	20% consolidated pumice sand	PP15-0670	2.62	1.09	58	23	25	33	16
958	IF04c		PP15-0671	2.62	0.82	69	25	27	41	29

986	EF08a	PP15-0651	40	57	48	15	30	43	36	11
755	EF08b	PP15-0652	19	37	31	10	19	36	30	10
788	EF08c	PP15-0653	21	25	23	11	28	34	31	15
837	EF09a	PP15-0654	38	51	48	26	32	43	40	22
926	EF09b	PP15-0655	34	45	41	19	31	40	37	17
863	EF09c	PP15-0656	36	49	47	24	36	49	47	24
760	EF12a	PP15-0657	43	81	67	27	24	45	38	15
874	EF12b	PP15-0658	39	73	59	24	23	44	35	15
946	EF12c	PP15-0659	29	65	57	20	18	40	35	12
742	EF11a	PP15-0660	29	32	31	21	36	40	38	26
780	EF11b	PP15-0661	40	60	51	27	28	42	36	19
956	EF11c	PP15-0662	49	63	58	21	35	46	42	15
923	EF10a	PP15-0663	15	30	25	19	15	30	26	19
995	EF10b	PP15-0664	34	63	55	22	22	40	35	14
706	EF10c	PP15-0665	28	33	30	15	26	30	27	14
747	IF05a	PP15-0666	25	33	30	16	27	35	33	18
762	IF05b	PP15-0667	51	63	60	26	31	38	36	16
844	IF05c	PP15-0668	36	44	42	17	35	43	42	17
839	IF04a	PP15-0669	32	44	40	20	27	38	34	18
932	IF04b	PP15-0670	27	32	30	16	29	35	33	17
958	IF04c	PP15-0671	51	53	50	15	42	43	41	12

Notes:

All samples collected by HBRC.

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 Capacity cited here is determined between total porosity and tension of -10 kPa. This may be referred to as Macro-porosity for specifications requiring this characteristic to be measured at -10 kPa. It is important to be aware what tension has been used, particularly with historical or NSD data.

Core No.	Site name	Sample ID	Gravimetric water content (%w/w)				Volumetric water content (%v/v)			
			Field moisture	-5 kPa	-10 kPa	-1500 kPa	Field moisture	-5 kPa	-10 kPa	-1500 kPa
906	EF01a	PP15-0621	32	35	33	14	37	41	39	16
940	EF01b	PP15-0622	28	37	33	14	31	41	37	15
996	EF01c	PP15-0623	17	30	28	16	21	38	35	20
918	EF02a	PP15-0624	19	51	43	19	17	44	37	17
794	EF02b	PP15-0625	12	27	24	18	12	27	24	18
975	EF02c	PP15-0626	11	23	21	16	9	19	18	13
731	EF03a	PP15-0627	18	36	34	19	20	39	37	21
833	EF03b	PP15-0628	18	32	30	23	21	38	36	28
955	EF03c	PP15-0629	17	34	33	23	20	39	38	26
738	IF01a	PP15-0630	49	69	63	29	33	46	42	20
841	IF01b	PP15-0631	29	37	34	17	30	39	36	18
929	IF01c	PP15-0632	47	59	57	36	39	48	47	29
703	IF02a	PP15-0633	71	110	84	33	28	44	33	13
909	IF02a	PP15-0634	66	91	74	40	30	42	34	18
990	IF02a	PP15-0635	77	88	78	41	40	46	40	21
825	IF03a	PP15-0636	65	68	65	27	51	54	51	21
911	IF03b	PP15-0637	26	33	29	19	28	36	32	21
988	IF03c	PP15-0638	42	51	43	32	30	37	31	23
818	EF05a	PP15-0639	49	67	59	38	30	42	37	24
977	EF05b	PP15-0640	60	77	69	47	37	48	43	29
993	EF05c	PP15-0641	39	44	41	30	33	38	35	26
806	EF04a	PP15-0642	35	47	43	25	30	40	37	22
878	EF04b	PP15-0643	29	44	38	28	26	39	33	24
927	EF04c	PP15-0644	30	49	45	28	24	39	36	22
734	EF06a	PP15-0645	17	32	28	12	20	38	33	14
821	EF06b	PP15-0646	16	25	22	9	22	34	31	12
961	EF06c	PP15-0647	15	25	22	11	20	33	30	14
835	EF07a	PP15-0648	53	77	65	26	29	41	35	14
867	EF07b	PP15-0649	60	76	63	17	34	43	35	9
964	EF07c	PP15-0650	60	91	79	29	23	36	31	11

References:

Gradwell, M.W. 1972: Methods for physical analysis of soils. *Scientific Report 10C*. Lower Hutt, N.Z. Soil Bureau.

John Dando
Laboratory manager

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ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512513	SPv1
Contact:	B Lynch	**Date Registered:**	09-Dec-2015	
	C/- Hawkes Bay Regional Council	**Date Reported:**	21-Dec-2015	
	Private Bag 6006	**Quote No:**	45046	
	NAPIER 4142	**Order No:**	N340202	
		Client Reference:	340-202	
		Submitted By:	K Hashiba	

Sample Type: Soil

Sample Name:		IF01-Env2015 0.1m 01-Dec-2015 10:00 am	IF02-Env2015 0.1m 01-Dec-2015 1:30 pm	IF03-Env2015 0.1m 01-Dec-2015 3:30 pm	IF04-Env2015 0.1m 07-Dec-2015 1:30 pm	IF05-Env2015 0.1m 07-Dec-2015 11:00 am
Lab Number:		1512513.1	1512513.2	1512513.3	1512513.4	1512513.5
Individual Tests						
Total Recoverable Uranium	mg/kg dry wt	0.76	0.73	0.77	0.42	0.43
Fluoride*	mg/kg dry wt	136	210	270	149	132
Heavy Metals with Mercury, Screen Level						
Total Recoverable Arsenic	mg/kg dry wt	3	5	7	8	6
Total Recoverable Cadmium	mg/kg dry wt	0.34	< 0.10	< 0.10	< 0.10	< 0.10
Total Recoverable Chromium	mg/kg dry wt	15	15	15	16	15
Total Recoverable Copper	mg/kg dry wt	16	14	18	5	5
Total Recoverable Lead	mg/kg dry wt	9.2	13.8	22	7.5	6.9
Total Recoverable Mercury	mg/kg dry wt	< 0.10	0.20	0.12	< 0.10	< 0.10
Total Recoverable Nickel	mg/kg dry wt	8	5	9	13	11
Total Recoverable Zinc	mg/kg dry wt	80	31	59	42	36
Organochlorine Pesticides Screening in Soil						
Aldrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
alpha-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
beta-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
delta-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
gamma-BHC (Lindane)	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
cis-Chlordane	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
trans-Chlordane	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
2,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total DDT Isomers	mg/kg dry wt	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Dieldrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan I	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan II	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan sulphate	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin aldehyde	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin ketone	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Heptachlor	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010

Sample Type: Soil						
Sample Name:		IF01-Env2015 0.1m 01-Dec-2015 10:00 am	IF02-Env2015 0.1m 01-Dec-2015 1:30 pm	IF03-Env2015 0.1m 01-Dec-2015 3:30 pm	IF04-Env2015 0.1m 07-Dec-2015 1:30 pm	IF05-Env2015 0.1m 07-Dec-2015 11:00 am
Lab Number:		1512513.1	1512513.2	1512513.3	1512513.4	1512513.5
Organochlorine Pesticides Screening in Soil						
Heptachlor epoxide	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Hexachlorobenzene	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Methoxychlor	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010

Sample Name:		EF01-ENV2015 0.1m 30-Nov-2015 9:00 am	EF02-ENV2015 0.1m 30-Nov-2015 11:30 am	EF03-ENV2015 0.1m 30-Nov-2015 1:30 pm	EF04-ENV2015 0.1m 02-Dec-2015 12:30 pm	EF05-ENV2015 0.1m 02-Dec-2015 10:00 am
Lab Number:		1512513.6	1512513.7	1512513.8	1512513.9	1512513.10
Individual Tests						
Total Recoverable Uranium	mg/kg dry wt	0.45	0.40	0.86	0.46	0.61
Fluoride*	mg/kg dry wt	186	171	240	149	179
Heavy Metals with Mercury, Screen Level						
Total Recoverable Arsenic	mg/kg dry wt	2	3	3	3	4
Total Recoverable Cadmium	mg/kg dry wt	0.10	0.18	0.68	0.16	< 0.10
Total Recoverable Chromium	mg/kg dry wt	6	4	7	11	14
Total Recoverable Copper	mg/kg dry wt	4	10	10	12	16
Total Recoverable Lead	mg/kg dry wt	6.7	5.8	7.2	9.0	10.4
Total Recoverable Mercury	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	0.11
Total Recoverable Nickel	mg/kg dry wt	4	3	10	6	7
Total Recoverable Zinc	mg/kg dry wt	25	43	66	57	48
Organochlorine Pesticides Screening in Soil						
Aldrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
alpha-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
beta-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
delta-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
gamma-BHC (Lindane)	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
cis-Chlordane	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
trans-Chlordane	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
2,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total DDT Isomers	mg/kg dry wt	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Dieldrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan I	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan II	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan sulphate	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin aldehyde	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin ketone	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Heptachlor	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Heptachlor epoxide	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Hexachlorobenzene	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Methoxychlor	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010

Sample Name:		EF06-ENV2015 0.1m 02-Dec-2015 3:30 pm	EF07-ENV2015 0.1m 03-Dec-2015 9:30 am	EF08-ENV2015 0.1m 03-Dec-2015 11:30 am	EF09-ENV2015 0.1m 04-Dec-2015 2:30 pm	EF10-ENV2015 0.1m 04-Dec-2015 12:30 pm
Lab Number:		1512513.11	1512513.12	1512513.13	1512513.14	1512513.15
Individual Tests						

Sample Type: Soil						
Sample Name:		EF06-ENV2015 0.1m 02-Dec-2015 3:30 pm	EF07-ENV2015 0.1m 03-Dec-2015 9:30 am	EF08-ENV2015 0.1m 03-Dec-2015 11:30 am	EF09-ENV2015 0.1m 04-Dec-2015 2:30 pm	EF10-ENV2015 0.1m 04-Dec-2015 12:30 pm
Lab Number:		1512513.11	1512513.12	1512513.13	1512513.14	1512513.15
Individual Tests						
Total Recoverable Uranium	mg/kg dry wt	0.52	0.28	0.37	0.79	0.43
Fluoride*	mg/kg dry wt	220	260	260	270	280
Heavy Metals with Mercury, Screen Level						
Total Recoverable Arsenic	mg/kg dry wt	4	< 2	< 2	3	3
Total Recoverable Cadmium	mg/kg dry wt	0.13	< 0.10	0.10	0.27	0.17
Total Recoverable Chromium	mg/kg dry wt	12	< 2	5	11	6
Total Recoverable Copper	mg/kg dry wt	3	2	< 2	9	6
Total Recoverable Lead	mg/kg dry wt	7.6	4.2	4.9	8.6	7.1
Total Recoverable Mercury	mg/kg dry wt	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Total Recoverable Nickel	mg/kg dry wt	9	< 2	4	12	3
Total Recoverable Zinc	mg/kg dry wt	33	21	25	55	38
Organochlorine Pesticides Screening in Soil						
Aldrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
alpha-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
beta-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
delta-BHC	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
gamma-BHC (Lindane)	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
cis-Chlordane	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
trans-Chlordane	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
2,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
2,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
4,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Total DDT Isomers	mg/kg dry wt	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06
Dieldrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan I	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan II	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endosulfan sulphate	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin aldehyde	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Endrin ketone	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Heptachlor	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Heptachlor epoxide	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Hexachlorobenzene	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Methoxychlor	mg/kg dry wt	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010

Sample Name:		EF11-ENV2015 0.1m 04-Dec-2015 5:00 am	EF12-ENV2015 0.1m 04-Dec-2015 8:30 am			
Lab Number:		1512513.16	1512513.17			
Individual Tests						
Total Recoverable Uranium	mg/kg dry wt	0.52	0.52	-	-	-
Fluoride*	mg/kg dry wt	220	250	-	-	-
Heavy Metals with Mercury, Screen Level						
Total Recoverable Arsenic	mg/kg dry wt	3	3	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.11	0.13	-	-	-
Total Recoverable Chromium	mg/kg dry wt	9	5	-	-	-
Total Recoverable Copper	mg/kg dry wt	6	5	-	-	-
Total Recoverable Lead	mg/kg dry wt	6.4	5.6	-	-	-
Total Recoverable Mercury	mg/kg dry wt	< 0.10	< 0.10	-	-	-

Sample Type: Soil						
Sample Name:		EF11-ENV2015 0.1m 04-Dec-2015 5:00 am	EF12-ENV2015 0.1m 04-Dec-2015 8:30 am			
Lab Number:		1512513.16	1512513.17			
Heavy Metals with Mercury, Screen Level						
Total Recoverable Nickel	mg/kg dry wt	5	3	-	-	-
Total Recoverable Zinc	mg/kg dry wt	34	27	-	-	-
Organochlorine Pesticides Screening in Soil						
Aldrin	mg/kg dry wt	< 0.010	< 0.010	-	-	-
alpha-BHC	mg/kg dry wt	< 0.010	< 0.010	-	-	-
beta-BHC	mg/kg dry wt	< 0.010	< 0.010	-	-	-
delta-BHC	mg/kg dry wt	< 0.010	< 0.010	-	-	-
gamma-BHC (Lindane)	mg/kg dry wt	< 0.010	< 0.010	-	-	-
cis-Chlordane	mg/kg dry wt	< 0.010	< 0.010	-	-	-
trans-Chlordane	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Total Chlordane [(cis+trans)* 100/42]	mg/kg dry wt	< 0.04	< 0.04	-	-	-
2,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	-	-	-
4,4'-DDD	mg/kg dry wt	< 0.010	< 0.010	-	-	-
2,4'-DDE	mg/kg dry wt	< 0.010	< 0.010	-	-	-
4,4'-DDE	mg/kg dry wt	< 0.010	0.063	-	-	-
2,4'-DDT	mg/kg dry wt	< 0.010	< 0.010	-	-	-
4,4'-DDT	mg/kg dry wt	< 0.010	0.011	-	-	-
Total DDT Isomers	mg/kg dry wt	< 0.06	0.07	-	-	-
Dieldrin	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Endosulfan I	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Endosulfan II	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Endosulfan sulphate	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Endrin	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Endrin aldehyde	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Endrin ketone	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Heptachlor	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Heptachlor epoxide	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Hexachlorobenzene	mg/kg dry wt	< 0.010	< 0.010	-	-	-
Methoxychlor	mg/kg dry wt	< 0.010	< 0.010	-	-	-

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**
Heavy Metals with Mercury, Screen Level	Dried sample, < 2mm fraction. Nitric/Hydrochloric acid digestion US EPA 200.2. Complies with NES Regulations. ICP-MS screen level, interference removal by Kinetic Energy Discrimination if required.	0.10 - 4 mg/kg dry wt	1-17
Organochlorine Pesticides Screening in Soil	Sonication extraction, SPE cleanup, dual column GC-ECD analysis (modified US EPA 8082).. Tested on dried sample	0.010 - 0.06 mg/kg dry wt	1-17
Total Fluoride in solids alkaline fusion*	Alkaline fusion of sample. Methods of Soil Analysis 2nd Edition, Pt2, 26-4.3.3.	-	1-17
Total Recoverable Uranium	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	0.10 mg/kg dry wt	1-17
Total Fluoride in solids*	Ion selective electrode. Methods of Soil Analysis 2nd Edition, Pt2, 26-4.3.3. (modified).	10 mg/kg dry wt	1-17

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.

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

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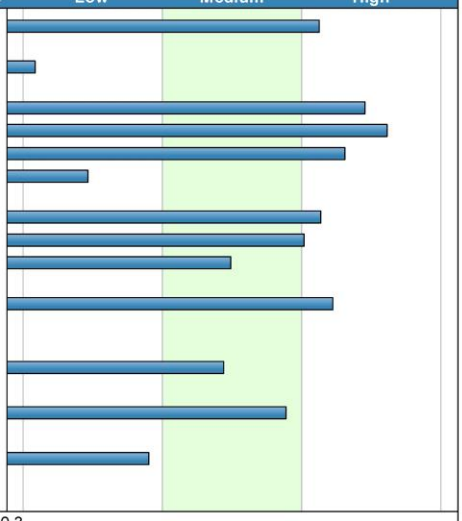
ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512914	shpv1
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: IF01-Agri2015 01-Dec-2015 10:00 am **Lab Number:** 1512914.1
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	6.4	5.8 - 6.3
Olsen Phosphorus	mg/L	6	20 - 30
Potassium	me/100g	1.07	0.50 - 0.80
Calcium	me/100g	20.0	6.0 - 12.0
Magnesium	me/100g	4.25	1.00 - 3.00
Sodium	me/100g	0.09	0.20 - 0.50
CEC	me/100g	30	12 - 25
Total Base Saturation	%	85	50 - 85
Volume Weight	g/mL	0.80	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	184	100 - 150
Anaerobically Mineralisable N*	µg/g	154	
Organic Matter*	%	11.4	7.0 - 17.0
Total Carbon*	%	6.6	
Total Nitrogen*	%	0.57	0.30 - 0.60
C/N Ratio*		11.6	
Anaerobically Mineralisable N/Total N Ratio*	%	2.7	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 3.6	Ca 67	Mg 14.2	Na 0.3
MAF Units	K 18	Ca 20	Mg 76	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.
IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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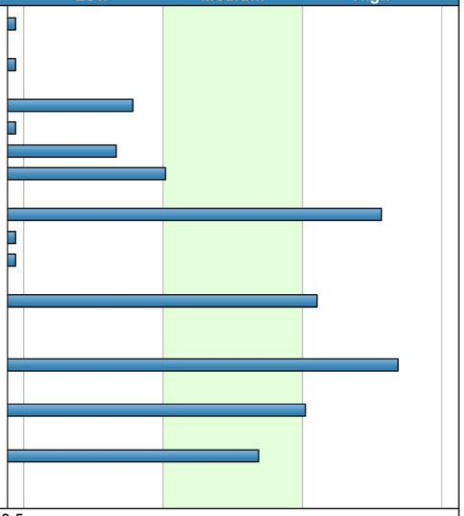
ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512914	shpv1
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: IF02-Agri2015 01-Dec-2015 1:30 pm **Lab Number:** 1512914.2
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	4.7	5.8 - 6.3
Olsen Phosphorus	mg/L	2	20 - 30
Potassium	me/100g	0.42	0.50 - 0.80
Calcium	me/100g	1.0	6.0 - 12.0
Magnesium	me/100g	0.76	1.00 - 3.00
Sodium	me/100g	0.21	0.20 - 0.50
CEC	me/100g	45	12 - 25
Total Base Saturation	%	5	50 - 85
Volume Weight	g/mL	0.40	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	166	100 - 150
Anaerobically Mineralisable N*	µg/g	276	
Organic Matter*	%	29.4	7.0 - 17.0
Total Carbon	%	17.1	
Total Nitrogen	%	0.63	0.30 - 0.60
C/N Ratio*		27.0	
Anaerobically Mineralisable N/Total N Ratio*	%	4.4	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 0.9	Ca 2	Mg 1.7	Na 0.5
MAF Units	K 3	Ca < 1	Mg 7	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. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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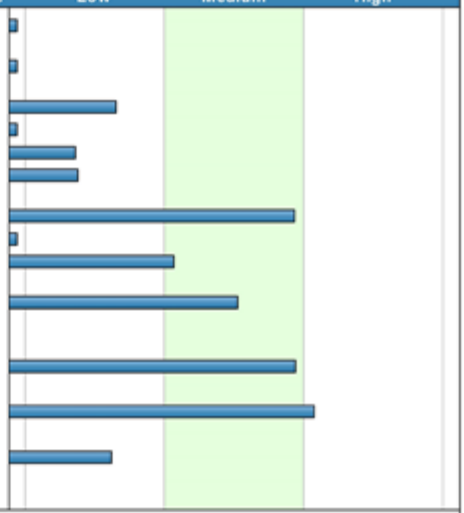
ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512914	shpv1
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: IF03-Agri2015 01-Dec-2015 3:30 pm **Lab Number:** 1512914.3
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.0	5.8 - 6.3
Olsen Phosphorus	mg/L	3	20 - 30
Potassium	me/100g	0.38	0.50 - 0.80
Calcium	me/100g	0.8	6.0 - 12.0
Magnesium	me/100g	0.55	1.00 - 3.00
Sodium	me/100g	0.08	0.20 - 0.50
CEC	me/100g	24	12 - 25
Total Base Saturation	%	8	50 - 85
Volume Weight	g/mL	0.63	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	126	100 - 150
Anaerobically Mineralisable N*	µg/g	134	
Organic Matter*	%	16.4	7.0 - 17.0
Total Carbon*	%	9.5	
Total Nitrogen*	%	0.71	0.30 - 0.60
C/N Ratio*		13.4	
Anaerobically Mineralisable N/Total N Ratio*	%	1.9	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 1.6	Ca 3	Mg 2.3	Na 0.3
MAF Units	K 5	Ca < 1	Mg 8	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.
IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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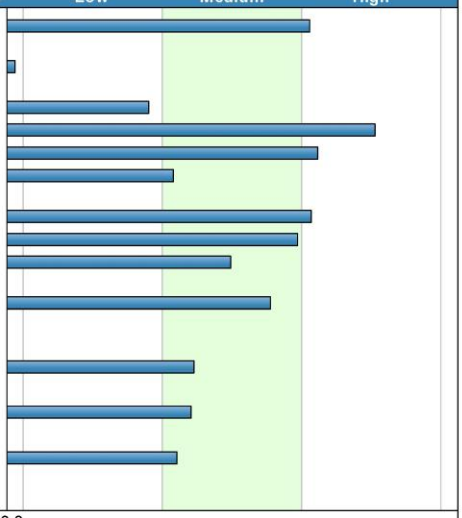
ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512914	shpv1
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: IF04-Agri2015 07-Dec-2015 1:30 pm **Lab Number:** 1512914.4
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	6.4	5.8 - 6.3
Olsen Phosphorus	mg/L	3	20 - 30
Potassium	me/100g	0.47	0.50 - 0.80
Calcium	me/100g	18.9	6.0 - 12.0
Magnesium	me/100g	3.47	1.00 - 3.00
Sodium	me/100g	0.22	0.20 - 0.50
CEC	me/100g	27	12 - 25
Total Base Saturation	%	84	50 - 85
Volume Weight	g/mL	0.80	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	139	100 - 150
Anaerobically Mineralisable N*	µg/g	116	
Organic Matter*	%	9.3	7.0 - 17.0
Total Carbon*	%	5.4	
Total Nitrogen*	%	0.36	0.30 - 0.60
C/N Ratio*		14.9	
Anaerobically Mineralisable N/Total N Ratio*	%	3.2	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 1.7	Ca 69	Mg 12.6	Na 0.8
MAF Units	K 8	Ca 19	Mg 62	Na 8

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. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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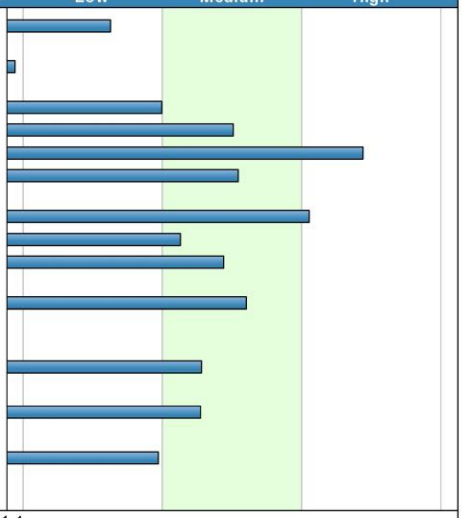
ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512914	shpv1
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: IF05-Agri2015 07-Dec-2015 11:00 am **Lab Number:** 1512914.5
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.5	5.8 - 6.3
Olsen Phosphorus	mg/L	4	20 - 30
Potassium	me/100g	0.50	0.50 - 0.80
Calcium	me/100g	9.1	6.0 - 12.0
Magnesium	me/100g	4.77	1.00 - 3.00
Sodium	me/100g	0.36	0.20 - 0.50
CEC	me/100g	27	12 - 25
Total Base Saturation	%	55	50 - 85
Volume Weight	g/mL	0.78	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	130	100 - 150
Anaerobically Mineralisable N*	µg/g	112	
Organic Matter*	%	9.8	7.0 - 17.0
Total Carbon*	%	5.7	
Total Nitrogen*	%	0.38	0.30 - 0.60
C/N Ratio*		14.9	
Anaerobically Mineralisable N/Total N Ratio*	%	2.9	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 1.9	Ca 34	Mg 17.7	Na 1.4
MAF Units	K 8	Ca 9	Mg 83	Na 13

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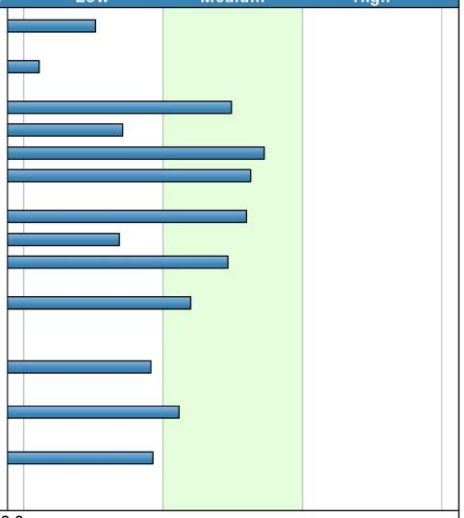
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF01-Agri2015 30-Nov-2015 9:00 am **Lab Number:** 1512914.6
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.4	5.8 - 6.3
Olsen Phosphorus	mg/L	7	20 - 30
Potassium	me/100g	0.65	0.50 - 0.80
Calcium	me/100g	4.8	6.0 - 12.0
Magnesium	me/100g	2.46	1.00 - 3.00
Sodium	me/100g	0.39	0.20 - 0.50
CEC	me/100g	20	12 - 25
Total Base Saturation	%	42	50 - 85
Volume Weight	g/mL	0.79	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	110	100 - 150
Anaerobically Mineralisable N*	µg/g	93	
Organic Matter*	%	6.4	7.0 - 17.0
Total Carbon*	%	3.7	
Total Nitrogen*	%	0.33	0.30 - 0.60
C/N Ratio*		11.1	
Anaerobically Mineralisable N/Total N Ratio*	%	2.8	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 3.3	Ca 24	Mg 12.4	Na 2.0
MAF Units	K 10	Ca 5	Mg 43	Na 14

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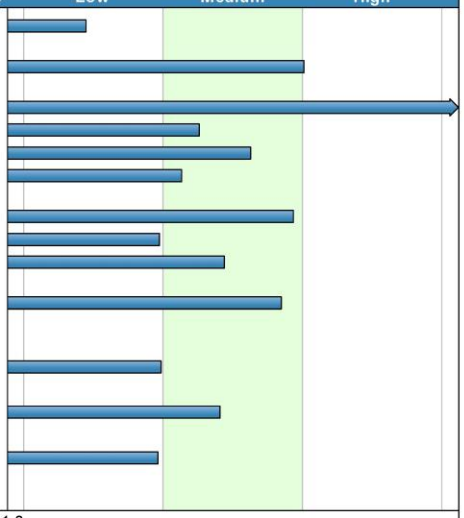
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF02-Agri2015 30-Nov-2015 11:30 am **Lab Number:** 1512914.7
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.4	5.8 - 6.3
Olsen Phosphorus	mg/L	31	20 - 30
Potassium	me/100g	1.86	0.50 - 0.80
Calcium	me/100g	7.6	6.0 - 12.0
Magnesium	me/100g	2.26	1.00 - 3.00
Sodium	me/100g	0.24	0.20 - 0.50
CEC	me/100g	24	12 - 25
Total Base Saturation	%	49	50 - 85
Volume Weight	g/mL	0.78	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	142	100 - 150
Anaerobically Mineralisable N*	µg/g	122	
Organic Matter*	%	6.9	7.0 - 17.0
Total Carbon*	%	4.0	
Total Nitrogen*	%	0.42	0.30 - 0.60
C/N Ratio*		9.4	
Anaerobically Mineralisable N/Total N Ratio*	%	2.9	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 7.7	Ca 31	Mg 9.4	Na 1.0
MAF Units	K 30	Ca 7	Mg 39	Na 9

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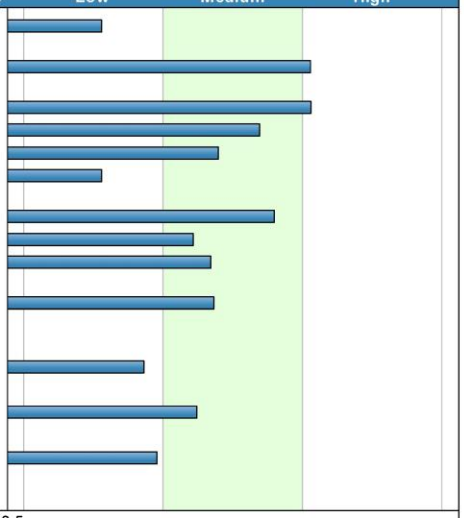
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF03-Agri2015 30-Nov-2015 1:30 pm **Lab Number:** 1512914.8
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.4	5.8 - 6.3
Olsen Phosphorus	mg/L	34	20 - 30
Potassium	me/100g	0.84	0.50 - 0.80
Calcium	me/100g	10.2	6.0 - 12.0
Magnesium	me/100g	1.79	1.00 - 3.00
Sodium	me/100g	0.11	0.20 - 0.50
CEC	me/100g	22	12 - 25
Total Base Saturation	%	58	50 - 85
Volume Weight	g/mL	0.74	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	118	100 - 150
Anaerobically Mineralisable N*	µg/g	107	
Organic Matter*	%	6.0	7.0 - 17.0
Total Carbon*	%	3.5	
Total Nitrogen	%	0.37	0.30 - 0.60
C/N Ratio*		9.4	
Anaerobically Mineralisable N/Total N Ratio*	%	2.9	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 3.7	Ca 45	Mg 8.0	Na 0.5
MAF Units	K 13	Ca 9	Mg 30	Na 4

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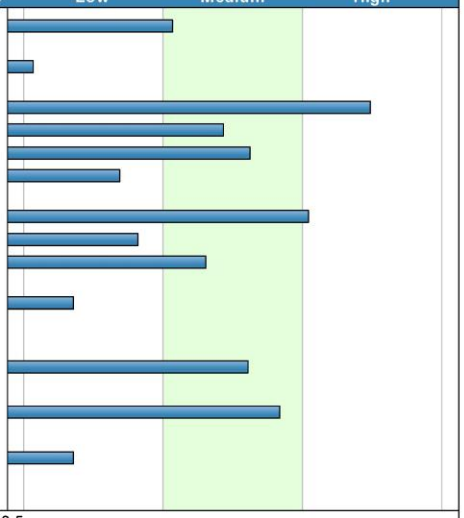
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF04-Agri2015 02-Dec-2015 12:30 pm **Lab Number:** 1512914.9
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.3
Olsen Phosphorus	mg/L	6	20 - 30
Potassium	me/100g	1.09	0.50 - 0.80
Calcium	me/100g	8.6	6.0 - 12.0
Magnesium	me/100g	2.25	1.00 - 3.00
Sodium	me/100g	0.14	0.20 - 0.50
CEC	me/100g	27	12 - 25
Total Base Saturation	%	45	50 - 85
Volume Weight	g/mL	0.72	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	68	100 - 150
Anaerobically Mineralisable N*	µg/g	63	
Organic Matter*	%	13.1	7.0 - 17.0
Total Carbon*	%	7.6	
Total Nitrogen*	%	0.55	0.30 - 0.60
C/N Ratio*		13.8	
Anaerobically Mineralisable N/Total N Ratio*	%	1.1	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 4.1	Ca 32	Mg 8.5	Na 0.5
MAF Units	K 16	Ca 8	Mg 37	Na 5

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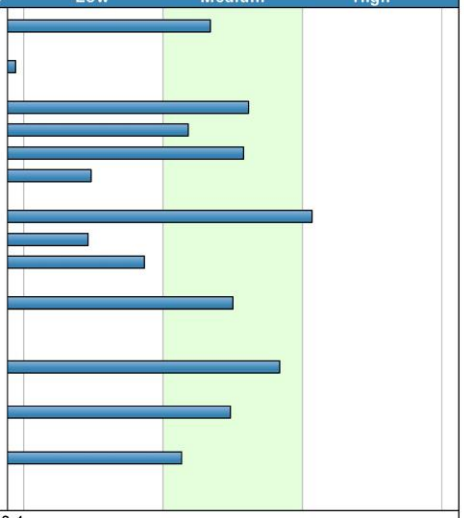
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF05-Agri2015 02-Dec-2015 10:00 am **Lab Number:** 1512914.10
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	6.0	5.8 - 6.3
Olsen Phosphorus	mg/L	4	20 - 30
Potassium	me/100g	0.68	0.50 - 0.80
Calcium	me/100g	7.1	6.0 - 12.0
Magnesium	me/100g	2.16	1.00 - 3.00
Sodium	me/100g	0.10	0.20 - 0.50
CEC	me/100g	27	12 - 25
Total Base Saturation	%	36	50 - 85
Volume Weight	g/mL	0.57	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	125	100 - 150
Anaerobically Mineralisable N*	µg/g	145	
Organic Matter*	%	15.4	7.0 - 17.0
Total Carbon	%	8.9	
Total Nitrogen	%	0.44	0.30 - 0.60
C/N Ratio*		20.1	
Anaerobically Mineralisable N/Total N Ratio*	%	3.3	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 2.5	Ca 26	Mg 7.9	Na 0.4
MAF Units	K 8	Ca 5	Mg 28	Na 3

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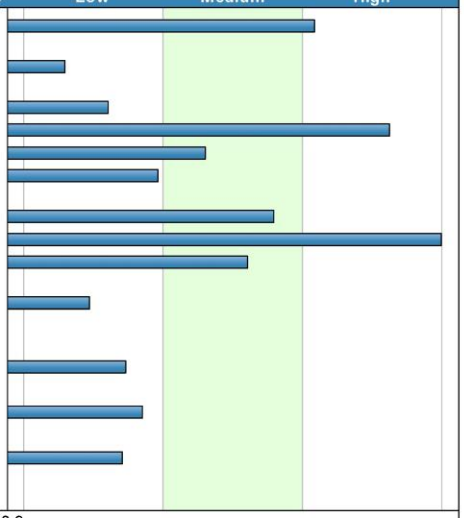
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF06-Agri2015 02-Dec-2015 3:30 pm **Lab Number:** 1512914.11
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	6.4	5.8 - 6.3
Olsen Phosphorus	mg/L	9	20 - 30
Potassium	me/100g	0.36	0.50 - 0.80
Calcium	me/100g	20.2	6.0 - 12.0
Magnesium	me/100g	1.61	1.00 - 3.00
Sodium	me/100g	0.19	0.20 - 0.50
CEC	me/100g	22	12 - 25
Total Base Saturation	%	100	50 - 85
Volume Weight	g/mL	0.84	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	73	100 - 150
Anaerobically Mineralisable N*	µg/g	58	
Organic Matter*	%	5.1	7.0 - 17.0
Total Carbon*	%	3.0	
Total Nitrogen*	%	0.27	0.30 - 0.60
C/N Ratio*		11.0	
Anaerobically Mineralisable N/Total N Ratio*	%	2.1	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 1.6	Ca 90	Mg 7.2	Na 0.9
MAF Units	K 6	Ca 21	Mg 31	Na 7

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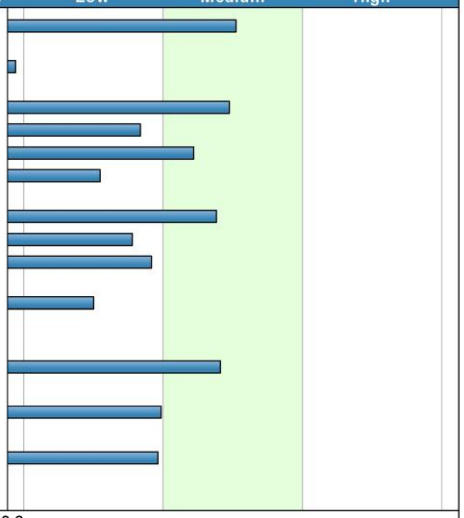
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF07-Agri2015 03-Dec-2015 9:30 am **Lab Number:** 1512914.12
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	6.1	5.8 - 6.3
Olsen Phosphorus	mg/L	3	20 - 30
Potassium	me/100g	0.64	0.50 - 0.80
Calcium	me/100g	5.4	6.0 - 12.0
Magnesium	me/100g	1.44	1.00 - 3.00
Sodium	me/100g	0.11	0.20 - 0.50
CEC	me/100g	17	12 - 25
Total Base Saturation	%	44	50 - 85
Volume Weight	g/mL	0.58	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	75	100 - 150
Anaerobically Mineralisable N*	µg/g	86	
Organic Matter*	%	11.1	7.0 - 17.0
Total Carbon	%	6.5	
Total Nitrogen	%	0.30	0.30 - 0.60
C/N Ratio*		21.7	
Anaerobically Mineralisable N/Total N Ratio*	%	2.9	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 3.8	Ca 32	Mg 8.5	Na 0.6
MAF Units	K 8	Ca 4	Mg 19	Na 3

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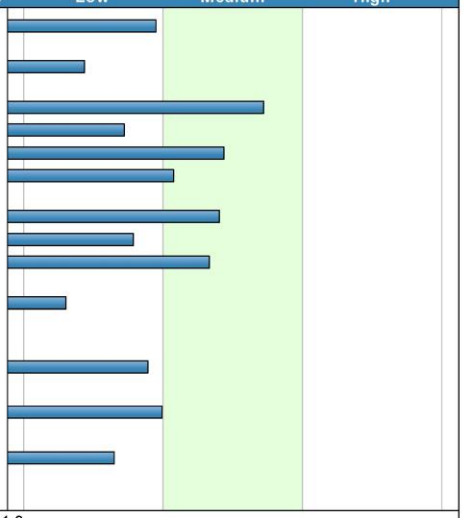
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF08-Agri2015 03-Dec-2015 11:30 am **Lab Number:** 1512914.13
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.3
Olsen Phosphorus	mg/L	12	20 - 30
Potassium	me/100g	0.72	0.50 - 0.80
Calcium	me/100g	4.9	6.0 - 12.0
Magnesium	me/100g	1.88	1.00 - 3.00
Sodium	me/100g	0.22	0.20 - 0.50
CEC	me/100g	17	12 - 25
Total Base Saturation	%	45	50 - 85
Volume Weight	g/mL	0.73	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	65	100 - 150
Anaerobically Mineralisable N*	µg/g	59	
Organic Matter*	%	6.2	7.0 - 17.0
Total Carbon*	%	3.6	
Total Nitrogen*	%	0.30	0.30 - 0.60
C/N Ratio*		12.1	
Anaerobically Mineralisable N/Total N Ratio*	%	2.0	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 4.2	Ca 28	Mg 10.9	Na 1.3
MAF Units	K 11	Ca 4	Mg 31	Na 8

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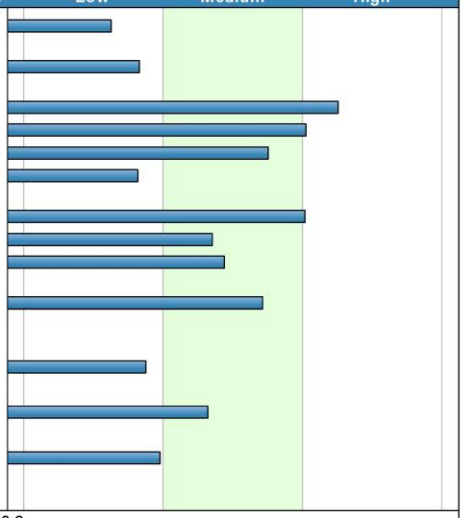
ANALYSIS REPORT

Client:	Hawkes Bay Regional Council	**Lab No:**	1512914	shpv1
Address:	Private Bag 6006 NAPIER 4142	**Date Registered:**	09-Dec-2015	
		Date Reported:	16-Dec-2015	
		Quote No:	45047	
		Order No:	N340202	
		Client Reference:	340-202	
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF09-Agri2015 04-Dec-2015 2:30 pm **Lab Number:** 1512914.14
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.5	5.8 - 6.3
Olsen Phosphorus	mg/L	17	20 - 30
Potassium	me/100g	0.95	0.50 - 0.80
Calcium	me/100g	12.4	6.0 - 12.0
Magnesium	me/100g	2.51	1.00 - 3.00
Sodium	me/100g	0.16	0.20 - 0.50
CEC	me/100g	26	12 - 25
Total Base Saturation	%	62	50 - 85
Volume Weight	g/mL	0.78	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	136	100 - 150
Anaerobically Mineralisable N*	µg/g	117	
Organic Matter*	%	6.1	7.0 - 17.0
Total Carbon*	%	3.6	
Total Nitrogen*	%	0.40	0.30 - 0.60
C/N Ratio*		9.0	
Anaerobically Mineralisable N/Total N Ratio*	%	2.9	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 3.7	Ca 48	Mg 9.8	Na 0.6
MAF Units	K 15	Ca 12	Mg 44	Na 6

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. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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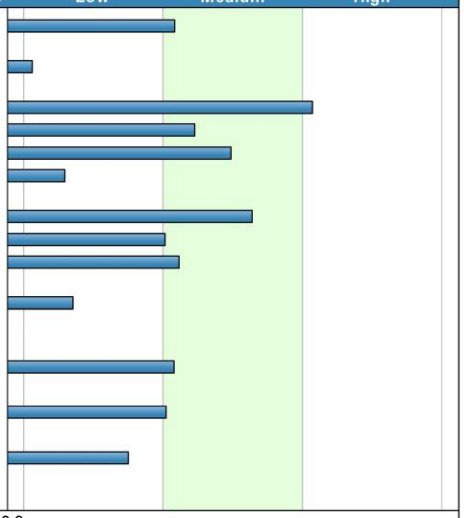
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF10-Agri2015 04-Dec-2015 12:30 pm **Lab Number:** 1512914.15
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.3
Olsen Phosphorus	mg/L	6	20 - 30
Potassium	me/100g	0.84	0.50 - 0.80
Calcium	me/100g	7.4	6.0 - 12.0
Magnesium	me/100g	1.98	1.00 - 3.00
Sodium	me/100g	0.06	0.20 - 0.50
CEC	me/100g	20	12 - 25
Total Base Saturation	%	50	50 - 85
Volume Weight	g/mL	0.65	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	68	100 - 150
Anaerobically Mineralisable N*	µg/g	70	
Organic Matter*	%	7.8	7.0 - 17.0
Total Carbon	%	4.5	
Total Nitrogen	%	0.31	0.30 - 0.60
C/N Ratio*		14.7	
Anaerobically Mineralisable N/Total N Ratio*	%	2.3	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 4.2	Ca 36	Mg 9.7	Na 0.3
MAF Units	K 11	Ca 6	Mg 29	Na < 2

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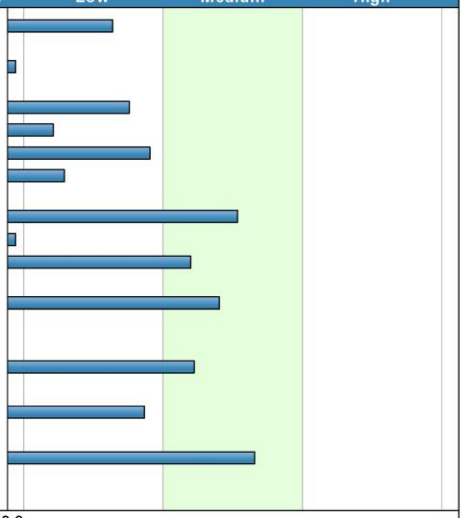
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF11-Agri2015 04-Dec-2015 9:50 am **Lab Number:** 1512914.16
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.5	5.8 - 6.3
Olsen Phosphorus	mg/L	4	20 - 30
Potassium	me/100g	0.41	0.50 - 0.80
Calcium	me/100g	2.8	6.0 - 12.0
Magnesium	me/100g	0.93	1.00 - 3.00
Sodium	me/100g	0.06	0.20 - 0.50
CEC	me/100g	19	12 - 25
Total Base Saturation	%	22	50 - 85
Volume Weight	g/mL	0.68	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	120	100 - 150
Anaerobically Mineralisable N*	µg/g	118	
Organic Matter*	%	9.2	7.0 - 17.0
Total Carbon	%	5.4	
Total Nitrogen	%	0.27	0.30 - 0.60
C/N Ratio*		19.6	
Anaerobically Mineralisable N/Total N Ratio*	%	4.3	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 2.2	Ca 15	Mg 4.9	Na 0.3
MAF Units	K 6	Ca 2	Mg 14	Na < 2

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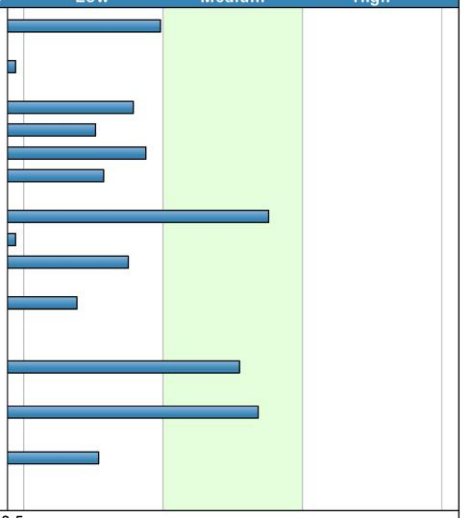
		Add. Client Ref:	Annual Soil tests	
Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Name: EF12-Agri2015 04-Dec-2015 8:30 am **Lab Number:** 1512914.17
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range
pH	pH Units	5.8	5.8 - 6.3
Olsen Phosphorus	mg/L	3	20 - 30
Potassium	me/100g	0.43	0.50 - 0.80
Calcium	me/100g	4.1	6.0 - 12.0
Magnesium	me/100g	0.91	1.00 - 3.00
Sodium	me/100g	0.11	0.20 - 0.50
CEC	me/100g	22	12 - 25
Total Base Saturation	%	25	50 - 85
Volume Weight	g/mL	0.55	0.60 - 1.00
Available Nitrogen (15cm Depth)*	kg/ha	69	100 - 150
Anaerobically Mineralisable N*	µg/g	84	
Organic Matter*	%	12.5	7.0 - 17.0
Total Carbon*	%	7.3	
Total Nitrogen*	%	0.51	0.30 - 0.60
C/N Ratio*		14.4	
Anaerobically Mineralisable N/Total N Ratio*	%	1.7	3.0 - 5.0
Soil Sample Depth*	mm	0-100	



Base Saturation %	K 1.9	Ca 19	Mg 4.2	Na 0.5
MAF Units	K 5	Ca 3	Mg 11	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. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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Analyst's Comments

Samples 1-17 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 1-17 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.

Sample 2 Comment:
The high CEC level found in this soil indicates that it has a high capacity to retain cation nutrients (potassium, calcium, magnesium and sodium). For crop and horticulture soil sample type codes, the normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g, unless otherwise denoted.

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.	-	1-17
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-17
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH.	0.1 pH Units	1-17
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry.	1 mg/L	1-17
Potassium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-17
Calcium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-17
Magnesium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 MAF units	1-17
Sodium (MAF)	1M Neutral ammonium acetate extraction followed by ICP-OES.	2 MAF units	1-17
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	1-17
Anaerobically Mineralisable N*	As for Available Nitrogen but reported as µg/g.	5 µg/g	1-17
Organic Matter*	Organic Matter is 1.72 x Total Carbon.	0.2 %	1-17
Total Carbon	Dumas combustion.	0.1 %	2, 10, 12, 15-16
Total Nitrogen	Dumas combustion.	0.04 %	2, 8, 10, 12, 15-16

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Phone:	06 835 9200	**Submitted By:**	K Hashiba	

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Total Carbon*	Determined by NIR, calibration based on Total Carbon by Dumas combustion.	0.1 %	1, 3-9, 11, 13-14, 17
Total Nitrogen*	Determined by NIR, calibration based on Total N by Dumas combustion.	0.04 %	1, 3-7, 9, 11, 13-14, 17
Potassium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.01 me/100g	1-17
Calcium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.5 me/100g	1-17
Magnesium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.04 me/100g	1-17
Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.05 me/100g	1-17
Potassium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-17
Calcium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	1 %BS	1-17
Magnesium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.2 %BS	1-17
Sodium (Sat)	1M Neutral ammonium acetate extraction followed by ICP-OES.	0.1 %BS	1-17
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	1-17
Total Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	5 %	1-17
Volume Weight	The weight/volume ratio of dried, ground soil.	0.01 g/mL	1-17

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.

FMCalvert

Fiona Calvert NZCS
Client Services Manager - Agriculture Division