

Soil Properties in the Rai/Pelorus Catchment

MDC Technical Report No: 12-005





Soil Properties in the Rai/Pelorus Catchment

MDC Technical Report No: 12-005

ISSN 1179-8181 (Print)
ISSN 1179-819X (Online)

ISBN 978-1-927159-12-5 (Print)
ISBN 978-1-927159-13-2 (Online)

File Ref/Record No: E355-004-008-02/1275715

March 2012

Report Prepared by:

Colin Gray

Environmental Scientist
Environmental Science & Monitoring Group

Marlborough District Council
Seymour Square
PO Box 443
Blenheim 7240
Phone: 520 7400
Website: www.marlborough.govt.nz

Acknowledgements:

The Marlborough District Council wish to thank the landowners and managers for providing access to their properties to allow soils to be sampled and supplying relevant site management information and Dr Iain Campbell for help in location of sampling sites, soil profile descriptions and comments on geomorphology of the catchment.

Executive Summary

Currently Council has detailed information for soils mapped on the Wairau Plain and the lower Awatere Valley. For the rest of Marlborough we have very little or more often no soils information available. For example, in the Rai/Pelorus catchment there is no available information on important soil parameters such as water holding capacity, drainage, soil depth and permeability. This kind of information is critical if we want to help landowners manage their soils for activities such as irrigation scheduling, effluent application, stock management etc. The aim of this study was therefore to describe and sample soils from representative sites in the Rai/Pelorus catchment and undertake a range of analysis for both topsoil and subsoils.

A series of soil auger observations were made across a range of sites in the Ronga, Tunakino, and Rai Valleys to identify soils which match the descriptions for the Ronga, Rai or Pelorus soil families previously mapped in this region. Seventeen soil profiles were described and soils analysed for a range of soil physical and chemical properties.

Three soil families were identified i.e. Rai, Ronga and Pelorus soils which occupied different parts of the landscape. The Rai family of soils occurred on the higher terraces and fan surfaces above the floodplain. The Ronga family of soils occurred on the lower valley floodplain surface, while the Pelorus family of soils occurred on the strongly undulating or hilly land in the transition zone between the steeply sloping valley sides and valley floor.

It was recognised that excavation and downcutting into the gravel aggradation surface and lower floodplain surface was not uniform and this has resulted in the formation of a series of degradation steps on these surfaces. More detailed soil mapping on these surfaces would likely separate out the most recent, recent and older Rai and Ronga soils presently all included in their respective soil families. While more detailed mapping on the undulating or hilly land in the transition zone between the steeply sloping valley sides and valley floor would probably separate out the Pelorus Steepland soils which have been previously mapped on the steep slopes.

All three soils were well drained, moderately deep to deep, had a moderate to moderately rapid permeability and have high water storage capacities. If this kind of fundamental information can be tied to real time soil moisture monitoring, it will allow landowners to match soil conditions with the optimal amount of irrigation or effluent to apply to land.

Contents

Executive Summary.....	i
1. Introduction	1
2. Aim.....	1
3. Material and Methods.....	1
3.1. Site	1
3.2. Soil Sampling.....	1
3.3. Soil Analyses	1
3.3.1. Chemical.....	1
3.3.2. Physical	2
4. Results and Discussion.....	2
4.1. General Setting.....	2
4.2. Previous Soil Investigations.....	2
4.3. Soil Characteristics	2
4.3.1. Rai Soil	2
4.3.2. Ronga Soil	4
4.3.3. Pelorus Soil.....	6
5. Future work	8
6. Summary.....	9
7. References	10
Appendix A	11
Appendix B	29

1. Introduction

Currently Council has detailed information for soils mapped on the Wairau Plain and the lower Awatere Valley. This information has been compiled by Landcare Research into soil fact sheets which summarise key properties (e.g. water holding capacity, soil depth) for a particular soil that can be used to help landowners better manage their soils. For the rest of Marlborough we only have very little or more often no soils information available. An example is the Rai/Pelorus catchment where there is no available information on important soil parameters such as water holding capacity, drainage, soil depth and permeability. This information is critical if we want to help landowners manage their soils for activities such as irrigation scheduling, effluent application, stock management etc. For example, you need to know how much capacity a soil has to assimilate effluent or irrigation and at what rate you can apply it safely without it ponding or running offsite.

2. Aim

The aim of this project is therefore to describe and sample soils from representative sites in the Rai/Pelorus catchment and undertake a range of analysis for both topsoil and subsoils. This information will be summarised into fact sheets and made available to landowners in the region.

3. Material and Methods

3.1. Site

A series of soil auger observations were made across a range of sites in the Ronga, Tunakino, and Rai Valleys to identify soils which match the descriptions for the Ronga, Rai or Pelorus soil families previously mapped in this region. When specific soils were identified a soil pit was dug to about 1 m depth and a detailed soil profile description was undertaken to confirm the soil type and to note any salient soil features that may affect soil management i.e. rooting depth, mottling, hardpans etc. In addition, details of the site were recorded such as slope, elevation, landform, parent material and soil drainage class.

3.2. Soil Sampling

From each pit bulk topsoil and subsoil samples were taken for chemical analysis. In addition duplicate undisturbed soil cores (100 mm diameter by 75 mm depth) were sampled. The soil cores were removed as one unit by excavation around the liner, bagged and loaded into padded crates for transport to the laboratory for analysis. These soil samples were used for soil physical analysis.

3.3. Soil Analyses

3.3.1. Chemical

Soil pH was measured in water using glass electrodes and a 2:1 water to soil ratio (Blackmore et al., 1987). Total carbon and nitrogen were determined by dry combustion of air-dry soil using a LECO 2000 CNS analyser (Blakemore et al., 1987). Olsen P was determined by extracting soils for 30 min with 0.5 M NaHCO₃ at pH 8.5 (Olsen, 1954) and measuring the phosphate concentration by the molybdenum blue method. Exchangeable cations i.e. Ca, Mg, K and Na were determined by extraction in ammonium acetate at pH 7 and analysed by ICP-OES. Anion storage capacity (Phosphate retention) was determined by equilibrium with 0.02 M potassium phosphate and analysis by ICP-OES. Anaerobically mineralisable nitrogen (AMN) was estimated by the anaerobic incubation method. The increase in NH₄-N concentration was measured after incubation for 7 days at 40 °C and extraction in 2 M KCl (Keeney and Bremner, 1966). Trace element concentrations in soils i.e. total recoverable copper, chromium, cadmium, arsenic, mercury, lead, nickel and zinc were determined by digesting soils in nitric/hydrochloric acid and analysing trace elements in the digest by inductively coupled plasma mass spectrometry (US EPA 200.2).

3.3.2. Physical

Dry bulk density was measured on soil samples extruded from cores and dried in an oven at 105°C until the weight remained constant and the sample was then weighed (Gradwell and Birrell, 1979). Particle density was measured by the pipette method. Soil water moisture content was determined at -5, -10, -100 and -1500 kPa tensions. This data was used to calculate Total Available Water (TAW). Total Available Water is the amount of water (in mm) that can be extracted between field capacity (-10kPa suction) and permanent wilting point (-1500 kPa). Total available water is effectively a measure of the amount of water storage there is in a soil. The capacity is affected by a range of soil properties including soil texture, structure, organic matter content, soil depth, profile layer and stone content.

4. Results and Discussion

4.1. General Setting

Throughout the South Island, glacial retreat in the Late Pleistocene resulted in extensive aggradation of gravels and the formation of a distinctive outwash terrace surface in most river valleys. These terrace deposits were later largely excavated during the warmer Post Glacial period to form the modern day floodplain system, with the outwash terrace commonly remaining at a slightly higher elevation as a discontinuous surface. While there was no accumulation of ice in the Marlborough Sounds region, valleys such as the Rai/Pelorus never-the-less display the same signal of Late Quaternary and Holocene climate change, with the formation of a distinctive Late Quaternary aggradational terrace (Dr Iain Campbell Pers. Comm.). Extensive fossil scree deposits in the Marlborough Sounds region (Campbell, 1996) indicate that the climate in the Late Last Glacial period was extremely cold with many bare ridges subject to frost action. These deposits, along with the subsequent deposition of the aggradational terrace gravels, indicate that in this region climate change from glacial to post-glacial conditions was extreme. Terrace remnants at slightly higher levels suggest that more than one cycle of climate change may be recorded.

4.2. Previous Soil Investigations

The valley floor soils of the Rai/Pelorus catchment were first identified during soil mapping of the region in the 1960's and published in 'Soils of South Island, New Zealand' (New Zealand Soil Bureau, 1968). This mapping however was undertaken at a small scale i.e. 1:250 000 and as stated in the published bulletin 'the survey does not give more than a general picture of the soil pattern'. The mapping identified the Ronga soil on the alluvial floodplain and low terrace land and the Rai soils on the higher terrace and fan surfaces above the floodplain. The Pelorus soil was mapped on the steep land areas in this catchment. A single soil profile description and basic soil chemistry from each profile is all there is available for each of these soils.

4.3. Soil Characteristics

In this investigation detailed soil profile descriptions were collected for the three soil families identified and previously mapped in the Rai/Pelorus catchment. This included 7 Ronga soils, 7 Rai soils and 3 Pelorus soils (Appendix A). From each profile basic soil chemistry, trace elements and soil physical data was also collected from both topsoil and subsoils (Appendix B).

4.3.1. Rai Soil

The Rai family of soils occur on the higher terraces and fan surfaces above the floodplain. However, the excavation and downcutting that occurred into the aggradation terrace surface was not uniform and it has resulted in a series of degradational steps in places (Figure 1). The Rai family therefore includes a range of soils that are related to steps in the river and stream downcutting process and vary in age and therefore the degree of weathering. Detailed mapping of this surface would probably separate Rai soils that occur on the different terraces and which have presently all been included in the Rai family.



Figure 1 The stepped degradation terrace with Rai family of soils occurring on both the higher terrace surface in the background and an intermediate terrace in the mid ground, with Ronga family soils occurring on the lower valley floodplain surface in the foreground.

The Rai soils are derived from gravelly greywacke/argillite alluvium. They are classified as a Brown soil in the New Zealand Soil Classification system (Hewitt, 2010). Although there was some variation in soil profile morphology, which reflected which terrace surface soils were sampled, generally there was a high degree of consistency. Typically topsoil profiles were dark yellowish brown, had a moderately developed fine polyhedral structure, a weak soil strength and were friable to very friable. Subsoils were typically yellowish brown, had a moderately developed fine polyhedral structure, a weak to very weak soil strength and were very friable.

Some average soil physical and chemical properties for the 7 Rai family soils sampled are given in Table 1. Typically the Rai soils are well drained, moderated deep to deep soils with a moderately rapid permeability. Topsoil textures are typically silt loams and very slightly stony that overly coarse stones at depth.

Total available water was calculated for both the 0-30cm and 0-60 cm soil depths. The 0-30 cm soil depth is particularly useful for soils where effluent is applied where the aim is to retain effluent within the root zone, while the deeper 0-60cm soil depth is useful for scheduling irrigation. For both soil depths storage capacity was classified as high.

Topsoil phosphate retention for the Rai soil was classed as high. Phosphate retention is a measure of the ability of the soil to remove phosphorus from solution, holding onto it firmly, tending to make it unavailable to plants. High P-retention values indicate that plants will give a lower response to the same amount of phosphate fertiliser than those plants on a soil with low P-retention.

Average topsoil cadmium concentrations were approximately double typical background concentrations found in soils (Roberts et al. 1984). The source of cadmium is most likely phosphate fertiliser which has been shown to contain cadmium as an incidental impurity. One Rai soil had a cadmium concentration above the suggested 0.6 mg kg^{-1} trigger value outlined in the national strategy for managing risks caused by cadmium in agricultural soils (MAF, 2010).

Table 1 Average soil properties for the Rai family of soils

Overview	
Family:	Rai
Soil Classification:	Brown
Parent material origin:	Gravelly greywacke/argillite alluvium
Average Physical properties	
Texture:	Silty - silty/skeletal
Potential rooting depth:	70 - 110cm
Soil depth:	Moderately deep to deep
Drainage class:	Well drained
Permeability:	Moderately rapid
Topsoil stones:	Very slightly stony
Top 30cm available water: (0-30cm)	73 mm (65 - 80mm)
Top 60cm available water: (0-60cm)	115mm (105 - 130mm)
Topsoil bulk density:	0.92 g/cm ³
Subsoil bulk density:	1.03 g/cm ³
Chemical properties	
Topsoil organic matter:	10.4 - 12.5%
Topsoil P retention:	High (71%)
Topsoil cadmium:	0.50 (mg/kg)

4.3.2. Ronga Soil

The Ronga family of soils occur on the lower valley floodplain surface, although like the Rai soil, excavation and downcutting into the more recent river surface has resulted in a stepwise progression of steps and an undulating surface (Figure 2). Detailed soil mapping would probably separate the most recent, recent and older recent Ronga soils within this surface, which have presently all been included in the Ronga family.



Figure 2 The undulating characteristics of the lower valley floodplain surface on which the Ronga family of soils occur.

The Ronga soils are derived from fine textured greywacke/argillite alluvium. They are classified as a Recent soil in the New Zealand Soil Classification system (Hewitt, 2010). There was variation in soil profile morphology which reflected where on the undulating surface soils were sampled. But in general soil profiles had brown to yellowish brown topsoils, had a weakly developed fine polyhedral structure, a weak soil strength, although a couple of sites were slightly firm, and soils were friable. Subsoils ranged from light olive brown to yellowish brown, had weakly or moderately developed fine polyhedral or fine block structure at a couple of sites, a weak soil strength and were very friable.

Some average soil physical and chemical properties for the 7 Ronga family soils are given in Table 2. Typically the Ronga soils are well drained, deep soils with a moderate to moderately rapid permeability. Topsoil textures are typically stoneless, silt loams which overly sandy textures. Like for the Rai soil, total available water for both the 0-30cm and 0-60 cm soil depth was classified as high.

Average topsoil phosphate retention for the Ronga topsoil was classed as medium. Like for the Rai soil average topsoil cadmium concentrations were approximately double typical background concentrations found in soils. Two Ronga soils had cadmium concentrations above the suggested 0.6 mg kg^{-1} trigger value outlined in the national strategy for managing risks caused by cadmium in agricultural soils (MAF, 2010).

Table 2 Average soil properties for the Ronga family of soils

Overview	
Family:	Ronga
Soil Classification:	Recent Fluvial
Parent material origin:	Fine textured greywacke/argillite alluvium
Average Physical properties	
Texture:	Silty - clayey
Potential rooting depth:	75 - 100cm
Soil depth:	Deep
Drainage class:	Well drained
Permeability:	Moderate to moderately rapid
Topsoil stones:	Stoneless
Top 30cm available water: (0-30cm)	84mm (67 - 101mm)
Top 60cm available water: (0-60cm)	133mm (123 - 146mm)
Topsoil bulk density:	1.17 g/cm ³
Subsoil bulk density:	1.34 g/cm ³
Chemical properties	
Topsoil organic matter:	5.4 - 7.6%
Topsoil P retention:	Medium (45%)
Topsoil cadmium:	0.51 (mg/kg)

4.3.3. Pelorus Soil

The transition from the steeply sloping valley sides to the valley floors in the Rai/Pelorus river valleys is in many places not abrupt and is sometimes marked by a zone of strongly undulating or hilly land. The Pelorus family of soils occurred in this zone. In places, these landscapes appear to represent large-scale debris with the dissected nature of the terrain suggesting deposition at some earlier time. It is possible that some of these deposits may have been triggered by tectonic activity (Dr Iain Campbell Pers. Comm.). The soils that were examined on these deposits are well weathered and at present are included in the Pelorus family although detailed mapping would probably separate these soils from Pelorus Steepland soils which have been previously mapped on the steep slopes.



Figure 3 The strongly undulating/hilly characteristics of the valley sides on which the Pelorus family of soils occur.

The Pelorus soils are derived from well weathered greywacke and argillite slope/colluvium deposits. They are classified as Brown soils in the New Zealand Soil Classification system (Hewitt, 2010). There was variation in soil profile morphology which reflected where on the surface soils were sampled. But in general soil profiles had dark yellowish brown topsoils, had variable structure ranging from moderately to strongly developed fine to medium polyhedral structure, a weak soil strength and soils were friable. Subsoils were yellowish brown to dark yellowish brown, had moderately to strongly developed fine polyhedral or medium block structure, a weak to very weak soil strength and were very friable.

Some average soil physical and chemical properties for the 3 Pelorus family soils are given in Table 3. Typically the Pelorus soils are well drained, moderated deep to deep soils with a moderately rapid permeability. Topsoil textures are typically silt loams, very slightly stony which overly coarse stones at depth. Total available water for both the 0-30cm and 0-60 cm soil depth was again classified as high for both soil depths.

Average topsoil phosphate retention for the Pelorus topsoil was classified as high. Like for the Rai and Ronga soils average topsoil cadmium concentrations were approximately double typical background concentrations found in soils, although no soils had a cadmium concentration above the suggested 0.6 mg kg^{-1} trigger value outlined in the national strategy for managing risks caused by cadmium in agricultural soils.

Table 3 Average soil properties for the Pelorus family of soils

Overview	
Family:	Pelorus
Soil Classification:	Brown
Parent material origin:	Greywacke and argillite slope/colluvium deposits
Average Physical properties	
Texture:	Silty - silty/skeletal
Potential rooting depth:	75 - 100cm
Soil depth:	Moderately deep to deep
Drainage class:	Well drained
Permeability:	Moderate to moderately rapid
Topsoil stones:	Very slightly stony
Top 30cm available water: (0-30cm)	76mm (73 - 79mm)
Top 60cm available water: (0-60cm)	111mm (107 - 115mm)
Topsoil bulk density:	0.97 g/cm ³
Subsoil bulk density:	1.09 g/cm ³
Chemical properties	
Topsoil organic matter:	10.3 - 13.6%
Topsoil P retention:	High (65%)
Topsoil cadmium:	0.47 (mg/kg)

5. Future work

- Install soil moisture monitoring probes in the Rai and Ronga soils. Data from these soil moisture probes could be available live on the Council website and used to advise landowners on when soil conditions are suitable for dairy effluent and irrigation water application.
- Undertake detailed soil mapping in the Rai/Pelorus catchment which would separate out the soils within the Rai, Ronga and Pelorus families.
- Undertake detailed soil mapping and collect soil information in other regions of Marlborough which are intensively farmed e.g. Tuamarina, Linkwater, Wairau Valley.

6. Summary

- Three soil families were identified in the Rai/Pelorus catchment i.e. Rai, Ronga and Pelorus.
- The Rai family of soils occurs on the higher terraces and fan surfaces above the floodplain. The Ronga family of soils occur on the lower valley floodplain surface, while the Pelorus family of soils occurred on the strongly undulating or hilly land in the transition zone between the steeply sloping valley sides and valley floor.
- It was recognised that excavation and downcutting into the gravel aggradation surface and lower floodplain surface was not uniform and this has resulted in the formation of a series of degradation steps on these surfaces. More detailed soil mapping on these surfaces would likely separate out the most recent, recent and older Rai and Ronga soils presently all included in their respective soil families. While more detailed mapping on the undulating or hilly land in the transition zone between the steeply sloping valley sides and valley floor would probably separate out the Pelorus Steepland soils which have been previously mapped on the steep slopes.
- All three soils were well drained, moderately deep to deep, moderate to moderately rapid permeability and have high water storage capacities.

7. References

New Zealand Soil Bureau 1968: General survey of the soils of the South Island, New Zealand. New Zealand Soil Bureau Bulletin 27. Includes maps at 1:250 000.

Blakemore, L.C., Searle, P.L., and Daly, B.K. (1987). Methods for chemical analysis of soils. New Zealand Soil Bureau Scientific Report No. 80 DSIR Soil Bureau, Lower Hutt.

Campbell, I.B. (1996). New occurrences and distribution of Kawakawa Tephra In South Island, New Zealand New Zealand Journal of Geology and Geophysics, 1986, Vol. 29: 425-435

Gradwell, M. W., and Birrell, K.S. (1979). Methods for physical analysis of soils. New Zealand Soil Bureau Scientific Report 10C.

Hewitt, A.E. (2010). New Zealand Soil Classification. 3rd Edition - Landcare Research Sciences Series 1. Lincoln New Zealand, Manaaki Whenua Press 2010.

Keeney, D.R., and Bremner, J.M. (1966). Comparison and evaluation of laboratory methods of obtaining an index of soil nitrogen availability. Agronomy Journal, 58: 498-503.

Olsen, S.R., Cole, C.V., Watanabe, F.S., and Dean, L.A. (1954). Estimation of available phosphorous in soils by extraction with sodium bicarbonate. US Department of Agriculture Circular 939. US Department of Agriculture, Washington DC.

Roberts, A.H.C, Longhurst, R.D., and Brown, M.W. (1984). Cadmium status of soils, plants, and grazing animals in New Zealand. New Zealand Journal of Agricultural Research, 37, 119-129.

Appendix A

Soil Profile Descriptions and Site Conditions

Sample Name: Site 1
 Soil Name: Rai
 GPS: 1648579 5428144
 Land use: Dairy
 Topography: Terrace
 Elevation: 44m
 Slope: 0°
 Soil material: loamy/stony old terrace alluvium from greywacke, argillite
 Soil drainage: Well

Horizon	Depth	Description
A	0-17cm	dark yellowish brown (10YR 4/4) silt loam; 5% medium to coarse partly stones; strongly developed fine polyhedral structure; weak soil strength; very friable; many fine roots
Bw1	17-35cm	yellowish brown (10YR 5/8) silt loam; 5% medium to coarse unweathered and partly weathered stones; strongly developed fine polyhedral structure; weak soil strength; very friable; many fine roots
Bw2	35-65cm	yellowish brown (10YR 5/8) sandy silt loam; 15% medium to very coarse unweathered and partly weathered stones; moderately developed fine polyhedral and weak blocky structure; weak soil strength; friable; few fine roots
BC	65-80cm+	yellowish brown to brownish yellow (10YR 5/8-6/8) sandy loam; 30% medium to very coarse unweathered and partly weathered stones; earthy; slightly firm; few fine roots



Sample name: Site 2

Soil Name: Rai

GPS: 1648588 5427986

Land use: Dairy

Topography: Terrace

Elevation: 40m

Slope: 0°

Soil material: loamy/stony old terrace alluvium from greywacke, argillite

Soil drainage: well



Horizon	Depth	Description
A	0-17cm	dark yellowish brown (10YR 4/4) silt loam; 2% medium to coarse stones; moderately to strongly developed fine polyhedral structure; weak soil strength; friable; many fine roots
Bw1	17-35cm	yellowish brown (10YR 5/8) sandy silt loam; 5% medium to coarse stones; moderately developed fine polyhedral structure; weak soil strength; very friable; common fine roots
Bw2	35-65cm	yellowish brown (10YR 5/8) sandy silt loam; 10% fine to coarse stones; moderately developed fine polyhedral structure; weak soil strength; very friable; few roots
BC	65-80cm+	yellowish brown (10YR 5/6) sandy loam; 15% fine to very coarse stones; weakly developed fine polyhedral structure; very weak soil strength; very friable; few roots

Sample name: Site 3
 Soil Name: Rai
 GPS: 1648504 5427970
 Land use: Conservation reserve
 Topography: Terrace
 Elevation: 50m
 Slope: 0°
 Soil material: loamy/stony old terrace alluvium from greywacke, argillite
 Soil drainage: well



Horizon	Depth	Description
O	2-0cm	dark reddish brown (5YR 3/2) peaty loam; apedal; structureless; very friable
A	0-20cm	dark yellowish brown (10YR 4/6) silt loam; 2% fine and medium stones; moderately developed fine polyhedral structure; very weak soil strength; very friable abundant fine and coarse roots
Bw1	20-45cm	yellowish brown (10YR 5/8) silt loam; 5% fine to coarse stones; moderately developed fine polyhedral structure; very weak soil strength; many fine and coarse roots
Bw2	45-70cm+	yellowish brown (10YR 5/6) silt loam; 5% fine to coarse stones; weakly developed fine polyhedral structure; weak soil strength; very friable; few fine roots

Sample name: Site 4

Soil Name: Ronga

GPS: 1648858 5427995

Land use: Dairy

Topography: Terrace

Elevation: 25m

Slope: 0°

Soil material: fine textured recent alluvium from greywacke, argillite etc

Soil drainage: well



Horizon	Depth	Description
A	0-11cm	brown to dark brown (10YR 4/3) silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots
(B)	11-45cm	light olive brown (2.5Y 5/6) silt loam; weakly developed fine polyhedral structure; weak soil strength; very friable; many fine roots
C1	45-60cm	light olive brown (2.5Y 5/6) silt loam; apedal; earthy; very weak soil strength; very friable; few fine roots
C2	60-90cm	light olive brown (2.5Y 5/6) fine sandy loam; apedal; earthy; very weak soil strength; very friable; very few fine roots

Sample name: Site 5
 Soil Name: Rai
 GPS: 1652356 5428592
 Land use: Dairy
 Topography: Terrace
 Elevation: 5m
 Slope: 0°
 Soil material: fine textured recent alluvium from greywacke, argillite etc
 Soil drainage: well



Horizon	Depth	Description
A	0-2cm	dark yellowish brown (10YR 4/4) silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots
A	2-20cm	dark yellowish brown (10YR 4/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots
(B)	20-42cm	dark yellowish brown to light olive brown (10YR 4/6-2.5Y 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; common fine roots
b (B)	52-90cm	dark yellowish brown (10YR 4/6) clay loam; 1% fine strong brown (7.5YR 5/8) and light yellowish brown (2.5Y 6/4) fine distinct mottles; moderately to strongly developed fine and medium polyhedral structure; weak soil strength; brittle; very few fine roots

Sample name: Site 6
 Soil Name: Rai
 GPS: 1649896 5436623
 Land use: Dairy
 Topography: Terrace
 Elevation: 54m
 Slope: 0°
 Soil material: partly weathered aggradational terrace alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-15cm	dark yellowish brown (10YR 4/4) silt loam; 2% medium stones; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots
AB	15-24cm	dark yellowish brown and yellowish brown (10YR 4/4 + 10YR 5/8) silt loam; 2% medium stones; moderately developed fine polyhedral structure; weak soil strength; friable
Bw1	24-40cm	dark yellowish brown (10YR 5/8) silt loam; 5% medium to coarse stones; moderately developed fine polyhedral and medium blocky structure; weak soil strength; very friable; few fine roots
Bw2	40-58cm	dark yellowish brown (10YR 5/8) silt loam; 15% medium to coarse stones; weakly developed fine polyhedral structure; weak soil strength; very friable; few fine roots
BC	40-70cm+	yellowish brown to light olive brown (10YR 5/6-2.5Y 5/6) sandy loam; 30% medium to coarse stones; apedal; single grain; loose; few fine roots

Sample name: Site 7
 Soil Name: Ronga
 GPS: 1649441 5435706
 Land use: Dairy
 Topography: Terrace
 Elevation: 36m
 Slope: 0°
 Soil material: fine textured recent alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-5cm	yellowish brown to dark yellowish brown (10YR 5/4-3/4) clay loam; apedal; earthy; slightly firm; many fine roots
A	5-19cm	yellowish brown to dark yellowish brown (10YR 5/4-3/4) clay loam; weakly developed fine polyhedral structure; slightly firm soil strength; friable; many fine roots
AB	19-29cm	yellowish brown and dark yellowish brown (10YR 5/4 +10YR 4/6) clay loam; weakly developed fine polyhedral structure; slightly firm; soil strength; friable; common fine roots
(B)	29-44cm	dark yellowish brown (10YR 4/6) clay loam; weakly developed fine blocky structure; slightly firm soil strength; friable; few fine roots
C1	44-80cm	light olive brown (2.5Y 5/6) sandy clay loam; weakly developed fine blocky structure; slightly firm soil strength; few fine roots
C2	80-95cm+	light olive brown to olive brown (2.5Y 5/4-4/4) sand; apedal; single grain; very few fine root

Sample name: Site 8
 Soil Name: Pelorus
 GPS: 1650856 5436154
 Land use: Dairy
 Topography: Terrace
 Elevation: 84m
 Slope: 10°
 Soil material: partly weathered slope detritus from argillite/greywacke
 Soil drainage: well



Horizon	Depth	Description
A	0-10cm	dark yellowish brown (10YR 4/4) silt loam; 5% fine to very coarse stones; moderately developed fine polyhedral and fine blocky structure; weak soil strength; friable; many fine roots
AB	10-14cm	yellowish brown and dark yellowish brown (10YR 5/8 + 10YR 4/4) silt loam; 5% fine to very coarse stones; moderately to strongly developed fine polyhedral structure; weak soil strength; very friable; common fine roots
Bw1	14-60cm	yellowish brown (10YR 5/8) silt loam; 15% fine to very coarse stones; moderately developed medium blocky and fine polyhedral structure; weak soil strength; very friable; few fine roots
Bw2	60-75cm+	yellowish brown (10YR 5/8) silt loam; 20% fine to very coarse stones; moderately developed fine polyhedral structure; weak soil strength; friable; few fine roots

Sample name: Site 9
 Soil Name: Ronga
 GPS: 1655554 5437424
 Land use: Dairy
 Topography: Terrace
 Elevation: 64m
 Slope: 0°
 Soil material: recent alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-10cm	dark yellowish brown (10YR 4/6) silt loam; weakly developed fine polyhedral structure; 2% medium stones; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots
AB	10-20cm	dark yellowish brown and light olive brown (10YR 4/6 + 2.5Y 5/6) silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots
(B)	20-52cm	light olive brown (2.5Y 6/2) silt loam; 5% medium to coarse stones; weakly developed fine blocky and polyhedral structure; weak soil strength; brittle; common fine roots
C1	52-68cm	light olive brown (2.5Y 5/6) sandy loam; 10% medium to coarse stones; apedal; earthy; very weak soil strength; very friable; few fine roots
C2	68-75cm+	light olive brown (2.5Y 5/6) sand; 20% medium to very coarse stones; apedal; single grain; loose; very few roots

Sample name: Site 10
 Soil Name: Rai
 GPS: 1654393 5437567
 Land use: Dairy
 Topography: Terrace
 Elevation: 73m
 Slope: 2°
 Soil material: partly weathered older alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-5cm	dark yellowish brown (10YR 4/4) clay loam; 2% reddish brown (2.5YR 4/4) fine distinct mottles; weakly developed medium blocky structure; slightly firm soil strength; brittle; many fine roots
A	5-28cm	dark yellowish brown (10YR 4/4) clay loam; 2% medium stones; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots
Bw1	28-57cm	dark yellowish brown (10YR 5/8) silt loam; 10% fine to medium stones; strongly developed fine polyhedral structure; very weak soil strength; very friable; many fine roots
Bw2	57-80cm	dark yellowish brown (10YR 4/4) silt loam; 15% fine to coarse stones; strongly developed fine polyhedral structure; weak soil strength; very friable; few fine roots
Bw3	80-110cm+	dark yellowish brown (10YR 4/4) silt loam; 15% fine to medium stones; weakly developed medium blocky structure; slightly firm; friable; few fine roots

Sample name: Site 11
 Soil Name: Pelorus
 GPS: 1654548 5437918
 Land use: Dairy
 Topography: Hill
 Elevation: 105m
 Slope: 14°
 Soil material: weathered slope detritus
 Soil drainage: well



Horizon	Depth	Description
A	0-14cm	dark yellowish brown (10YR 4/6) heavy silt loam; 2% medium to coarse stones; moderately developed medium polyhedral structure; weak soil strength; friable; many fine roots
AB	14-19cm	dark yellowish brown and yellowish brown (10YR 4/6 +10YR 5/8) heavy silt loam; 5% medium to coarse stones; strongly developed fine polyhedral structure; very weak soil strength; very friable; many fine roots
Bw1	19-38cm	yellowish brown (10YR 5/8) heavy silt loam; 5% medium to coarse stones; strongly developed fine polyhedral structure; very weak soil strength; very friable; common fine roots
Bw2	38-58cm	yellowish brown (10YR 5/8) heavy silt loam; 10% medium to very coarse stones; moderately developed fine polyhedral structure; very weak soil strength; friable; few fine roots
Bw3	58-100cm	yellowish brown (10YR 5/6) clay loam; 15% medium to very coarse stones; 5% light olive brown (2.5Y 6/4) and 5% red (2.5YR 4/8) medium distinct mottles associated with weathering clasts; moderately developed medium polyhedral and blocky structure; slightly firm soil strength; friable; very few roots

Sample name: Site 12
 Soil Name: Ronga
 GPS: 1654088 5437477
 Land use: Dairy
 Topography: Hill
 Elevation: 61m
 Slope: 0°
 Soil material: recent alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-4cm	yellowish brown (10YR 5/4) heavy silt loam; 1% fine to medium stones; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots;
A	4-12cm	yellowish brown (10YR 5/4) silt loam; weakly developed fine polyhedral structure; very weak soil strength; very friable; common fine roots
(B)	12-30cm	light olive brown (2.5Y 5/6) silt loam; weakly developed fine polyhedral structure; very weak soil strength; very friable; very few fine roots
C1	30-55cm	light olive brown (2.5Y 5/6) fine sandy loam; apedal; earthy; very weak soil strength; few fine roots
C2	55-65cm	light olive brown (2.5Y 5/6) sand; 20% fine stones; apedal; single grain; loose
C3	65-100cm	light olive brown (2.5Y 5/6) loamy sand; apedal; earthy; loose

Sample name: Site 13
 Soil Name: Rai
 GPS: 1653122 5428825
 Land use: Dairy
 Topography: Terrace
 Elevation: 16m
 Slope: 0°
 Soil material: weathered terrace alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-18cm	dark yellowish brown (10YR 4/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots
AB	18-25cm	dark yellowish brown and yellowish brown (10YR 4/4+ 10YR 5/8) silt loam; 1% coarse stones; moderately developed fine polyhedral structure; weak soil strength; very friable; many fine roots
Bw1	25-40cm	yellowish brown (10YR 5/8) silt loam; 1% coarse stones; moderately developed fine polyhedral and medium blocky structure; weak soil strength; very friable; common fine roots
Bw2	40-58cm	yellowish brown (10YR 5/8) fine sandy loam; weakly developed fine polyhedral and medium blocky structure; weak soil strength; friable; few fine roots
BC	58-75cm+	yellowish brown (10YR 5/8) sandy silt loam; 35% medium to very coarse stones; very weakly developed fine polyhedral structure; friable; few fine roots

Sample name: Site 14
 Soil Name: Ronga
 GPS: 1653102 5428990
 Land use: Dairy
 Topography: Terrace
 Elevation: 12m
 Slope: 0°
 Soil material: silty alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-3cm	brown to dark brown (10YR 4/3) silt loam; apedal; earthy; weak soil strength; slightly firm; common fine roots
A	3-12cm	brown to dark brown (10YR 4/3) silt loam; weakly developed fine polyhedral structure; weak soil strength; very friable; many fine and few medium roots
AC	12-28cm	brown to dark brown (10YR 4/3) and yellowish brown (10YR 4/6) silt loam; weakly developed fine polyhedral structure; weak soil strength; very friable; few fine roots
C1	28-62cm	dark yellowish brown to dark brown (10YR 4/6-5/6) silt loam; apedal; earthy; very weak soil strength; very friable; few fine roots
C2	62-90cm+	dark yellowish brown to dark brown (10YR 4/6-5/6) sandy loam; few faint mottles; apedal; earthy; very weak soil strength; very friable;

Sample name: Site 15
 Soil Name: Pelorus
 GPS: 1653715 5428717
 Land use: Dairy
 Topography: Terrace
 Elevation: 25m
 Slope: 6°
 Soil material: weathered detritus over weathering argillite
 Soil drainage: well

Horizon	Depth	Description
A	0-12cm	dark yellowish brown (10YR 4/6) heavy silt loam; strongly developed fine and medium polyhedral structure; weak soil strength; friable; abundant fine roots
AB	12-17cm	dark yellowish brown and yellowish brown (10YR 4/6 + 10YR 5/8) heavy silt loam; strongly developed fine polyhedral structure; weak soil strength; very friable; many fine roots
Bw1	17-40cm	dark yellowish brown (10YR 5/8-6/8) clay loam; 2% partly weathered medium stones; strongly developed fine polyhedral structure; very weak soil strength; very friable; common fine roots
BC	40-75cm+	brownish yellow (10YR 6/8) clay loam; 80% coarse to very coarse weathered stony bedrock; apedal; earthy; very firm; few fine roots



Sample name: Site 16
 Soil Name: Rai
 GPS: 1650192 5437119
 Land use: Dairy
 Topography: Terrace
 Elevation: 51m
 Slope: 6°
 Soil material: partly weathered gravelly alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-14cm	dark yellowish brown (10YR 4/4) silt loam; 1% medium stones; moderately developed fine and medium polyhedral structure; weak soil strength; friable; abundant fine roots
AB	14-20cm	yellowish brown and dark yellowish brown (10YR 5/8 + 10YR 4/4) silt loam; 3% fine stones; moderately developed fine polyhedral; structure; weak soil strength; friable; many fine roots
Bw1	20-37cm	yellowish brown (10YR 5/8) silt loam; 5% fine to medium stones; moderately developed fine polyhedral structure; very weak soil strength; very friable; few fine roots
Bw2	37-65cm+	yellowish brown (10YR 5/8) sandy loam; 7% fine to coarse stones; weakly developed fine polyhedral structure; very weak soil strength; very friable; few fine roots
BC	65-80cm+	light olive brown to yellowish brown (2.5Y 5/6-10YR 5/6) coarse sand; 60% fine to very coarse stones; apedal; single grain; loose; few fine roots

Sample name: Site 17
 Soil Name: Ronga
 GPS: 1649837 5437285
 Land use: Dairy
 Topography: Terrace
 Elevation: 47m
 Slope: 0°
 Soil material: weakly weathered fine textured alluvium
 Soil drainage: well



Horizon	Depth	Description
A	0-22cm	dark yellowish brown (10YR 4/4) heavy silt loam; moderately developed fine polyhedral structure; slightly firm soil strength; friable; many fine roots
AB	22-35cm	dark yellowish brown (10YR 4/4) and light olive brown to yellowish brown (2.5Y 5/6-10YR 5/6) heavy silt loam; strongly developed fine polyhedral structure; weak soil strength; very friable; common fine roots
(B)	35-50cm	light olive brown to yellowish brown (2.5Y 5/6-10YR 5/6) heavy silt loam; moderately developed fine polyhedral and blocky structure; very weak soil strength; very friable; few fine roots
C	50-90cm	light olive brown (2.5Y 5/6) silt loam; apedal; earthy; very weak soil strength; brittle; few fine roots

Appendix B

Soil Chemical, Trace Element and Physical Results

Soil Chemical Properties

Site	Soil	Soil Hor	Soil Depth	pH	Olsen P	P Ret	AMN	OM	Total C	Total N	K	Ca	Mg	Na	BS	CEC
					mg/L	%	µg/g	%	%	%	me/100g	me/100g	me/100g	me/100g	%	me/100g
Site 1	Rai	A	0 - 10 cm	6.0	25	77	242	11.7	6.8	0.62	1.43	12.1	1.58	0.08	53	29
		Bw2	40 - 50 cm	5.3	7	92	48	5.5	3.2	0.29	0.91	0.9	0.15	< 0.05	10	21
Site 2	Rai	A	0 - 10 cm	6.3	30	71	200	10.4	6	0.54	0.24	16.3	0.35	0.06	58	29
		BW2	30 - 40 cm	5.7	3	94	26	4.3	2.5	0.2	0.06	1.1	0.1	< 0.05	8	16
Site 3	Rai	A	0 - 10 cm	5.4	5	81	122	10.4	6	0.53	0.6	6.7	2.2	0.1	34	28
		BW1	30 - 40 cm	5.3	4	94	35	6.2	3.6	0.33	0.11	< 0.5	0.24	0.08	< 5	18
Site 4	Ronga	A	0 - 10 cm	5.9	49	47	145	6.1	3.6	0.39	0.16	13.4	1.97	0.07	61	25
		B	30 - 40 cm	5.6	3	69	12	1	0.6	0.08	0.07	4.5	1.88	0.07	38	17
Site 5	Ronga	A	0 - 10 cm	6.1	25	48	179	6.5	3.8	0.45	0.27	12.9	2.08	0.08	64	24
		B	30 - 40 cm	5.7	5	56	62	2.8	1.6	0.2	0.2	6.4	1.8	0.07	45	19
Site 6	Rai	A	0 - 10 cm	5.9	38	69	222	12.5	7.3	0.69	0.26	14.2	1.55	0.05	54	30
		Bw1	30 - 40 cm	5.4	11	92	45	5.2	3	0.28	0.09	1.3	0.22	< 0.05	8	22
Site 7	Ronga	A	0 - 10 cm	5.9	53	47	150	5.4	3.1	0.37	0.34	16.2	1.14	0.24	66	27
		B	30 - 40 cm	6	8	45	33	1.4	0.8	0.11	0.13	9.9	0.65	0.08	54	20
Site 8	Pelorus	A	0 - 10 cm	5.6	37	70	258	13.6	7.9	0.72	0.43	14.7	0.83	0.12	46	35
		BW1	25- 35 cm	5.6	5	89	33	5.3	3.1	0.27	0.13	2.9	0.2	0.06	17	20
Site 9	Ronga	A	0 - 10 cm	5.9	14	48	137	5.9	3.4	0.38	0.2	14.6	0.86	0.07	62	26

		B	25- 35 cm	5.6	3	52	36	1.7	1	0.13	0.09	7.6	0.29	< 0.05	44	18
Site 10	Rai	A	0 - 10 cm	5.6	28	68	197	11.3	6.6	0.64	0.64	10.7	1.51	0.09	45	29
		BW1	35 - 45 cm	5.9	5	81	35	4.1	2.4	0.22	0.1	2.2	0.21	0.08	16	16
Site 11	Pelorus	A	0 - 10 cm	5.8	21	68	210	10.7	6.2	0.56	0.29	14.7	1.1	0.06	54	30
			NONE	5.9	5	90	26	5.6	3.2	0.24	0.12	5.5	0.39	0.07	30	21
Site 12	Ronga	A	0 - 10 cm	5.9	14	42	185	6.2	3.6	0.43	0.73	12.1	1.47	0.1	62	23
			30 - 40 cm	5.8	5	45	34	1.3	0.8	0.11	0.1	6.2	0.86	0.13	47	16
Site 13	Rai	A	0 - 10 cm	5.5	36	74	206	12.4	7.2	0.64	2.24	9.4	1.24	0.12	39	34
		BW1	30 - 40 cm	5.1	6	96	43	5.7	3.3	0.27	0.3	0.9	0.2	0.07	7	23
Site 14	Ronga	A	0 - 10 cm	6.4	15	37	222	6.8	4	0.4	0.2	15.6	4.29	0.15	77	26
		C1	30 - 40 cm	6.8	2	49	50	1.3	0.8	0.1	0.11	8.8	7.25	0.1	77	21
Site 15	Pelorus	A	0 - 10 cm	6	47	58	281	10.3	6	0.59	0.58	14.9	2	0.13	58	30
		BW1	30 - 40 cm	5.5	8	79	84	3.6	2.1	0.22	0.28	3.8	0.68	0.09	23	21
Site 16	Rai	A	0 - 10 cm	6.3	37	64	213	12.3	7.1	0.7	1.62	18.5	2.05	0.1	66	34
		BW1	30 - 40 cm	5.4	5	93	43	6.1	3.6	0.28	0.73	1.5	0.24	< 0.05	12	21
Site 17	Ronga	A	0 - 10 cm	6.1	33	52	234	7.6	4.4	0.51	0.29	16.7	1.29	0.07	67	27
		B	30 - 40 cm	6.1	5	63	55	2.7	1.6	0.18	0.11	8.9	0.41	0.06	50	19

Soil Trace Element Concentrations

Site	Soil	Soil Hori	Soil Depth	Zn	Cu	Cr	As	Pb	Ni	Hg	Cd
				mg/kg							
Site 1	Rai	A	0 - 10 cm	51	14	76.4	5.1	12.33	32.9	0.15	0.41
		Bw2	40 - 50 cm	65	31	94.4	4.9	15.92	49.7	0.21	0.09
Site 2	Rai	A	0 - 10 cm	48	13	119	4.2	10.59	37.6	0.1	0.4
		BW2	30 - 40 cm	69	25	118.3	3.9	14.02	73.1	0.15	0.07
Site 3	Rai	A	0 - 10 cm	82	15	93.5	3.6	11.46	43.7	0.2	0.06
		BW1	30 - 40 cm	82	21	109.3	4.1	12.87	62	0.21	0.05
Site 4	Ronga	A	0 - 10 cm	57	21	185.6	4.1	9.58	120.7	0.07	0.25
		B	30 - 40 cm	62	22	204	3.4	10.84	118.5	0.06	0.06
Site 5	Ronga	A	0 - 10 cm	63	26	190.9	4.9	11.21	134.3	0.08	0.36
		B	30 - 40 cm	68	27	197.8	3.7	10.33	143	0.13	0.11
Site 6	Rai	A	0 - 10 cm	125	38	47	5.2	121.4	19.3	0.35	0.37
		Bw1	30 - 40 cm	86	18	62	5.4	18.17	27.4	0.22	0.1
Site 7	Ronga	A	0 - 10 cm	74	25	74.7	4.8	12.97	44.5	0.11	0.82
		B	30 - 40 cm	66	20	72.3	3.8	13.05	44.7	0.08	0.1
Site 8	Pelorus	A	0 - 10 cm	59	44	46.8	6.1	11.77	20.2	0.12	0.57
		BW1	25- 35 cm	72	24	54.1	6.1	14.17	22.2	0.17	0.13
Site 9	Ronga	A	0 - 10 cm	59	14	46	4.4	13.19	25.3	0.05	0.44

		B	25 - 35 cm	55	15	43.6	3.6	13.26	24.9	0.06	0.09
Site 10	Rai	A	0 - 10 cm	69	20	62.8	6.3	12.12	26.3	0.1	0.53
		BW1	35 - 45 cm	79	29	106.2	6.7	14.27	60.9	0.1	0.1
Site 11	Pelorus	A	0 - 10 cm	58	18	26.5	5.8	13.82	12	0.12	0.53
			NONE	72	27	38.4	6.3	20.8	19.7	0.17	0.07
Site 12	Ronga	A	0 - 10 cm	66	15	40.9	3.9	13.9	21.7	0.05	0.46
			30 - 40 cm	62	17	42.6	3.4	13.58	23.7	0.05	0.13
Site 13	Rai	A	0 - 10 cm	45	13	113.4	4.1	11.17	52.9	0.11	0.28
		BW1	30 - 40 cm	56	14	147.9	3.7	12.63	63	0.19	0.07
Site 14	Ronga	A	0 - 10 cm	60	30	229	4.2	9.56	179.4	0.07	0.24
		C1	30 - 40 cm	59	29	212	3.4	9.39	174.3	0.08	0.09
Site 15	Pelorus	A	0 - 10 cm	48	11	29.3	4.8	12	13.7	0.09	0.31
		BW1	30 - 40 cm	58	12	30.2	4.7	15.91	13.9	0.11	0.06
Site 16	Rai	A	0 - 10 cm	65	14	41.9	3.9	11.81	14.8	0.1	0.98
		BW1	30 - 40 cm	55	11	52.4	3.4	12.76	19.3	0.18	0.1
Site 17	Ron	A	0 - 10 cm	103	19	55.6	4	12.83	30.4	0.07	1.01
		B	30 - 40 cm	77	18	63.1	3.6	13.91	32.9	0.09	0.1

Soil Physical Properties

Site	Soil	Soil Hori	Soil Depth	Bulk density	Particle density	Total porosity	Macro-porosity	Air filled porosity	-5kPa	-10kPa	-100kPa	-1500kP	Total available water	Readily available water
				(t/m ³)	(t/m ³)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
Site 1	Rai	A	0 - 10 cm	0.88	2.52	65.25	9.90	12.10	55.30	53.15	45.00	26.80	26.35	8.15
		Bw2	40 - 50 cm	1.01	2.68	62.45	16.70	19.75	45.75	42.70	35.70	28.80	13.90	7.00
Site 2	Rai	A	0 - 10 cm	0.96	2.56	62.45	4.85	7.30	57.60	55.15	45.95	28.60	26.55	9.20
		BW2	30 - 40 cm	1.07	2.72	60.45	15.05	17.90	45.40	42.55	36.70	30.10	12.45	5.85
Site 3	Rai	A	0 - 10 cm	0.76	2.62	71.10	17.70	20.30	53.40	50.80	42.20	28.25	22.55	8.60
		BW1	30 - 40 cm	1.02	2.69	61.90	13.40	15.65	48.55	46.25	40.95	32.15	14.10	5.30
Site 4	Ronga	A	0 - 10 cm	1.10	2.68	59.10	4.85	6.95	54.25	52.15	44.10	21.70	30.45	8.05
		B	30 - 40 cm	1.45	2.78	47.75	4.70	5.85	43.05	41.90	37.95	28.85	13.05	3.95
Site 5	Ronga	A	0 - 10 cm	1.18	2.70	56.25	3.90	5.90	52.35	50.35	43.20	23.45	26.90	7.15
		B	30 - 40 cm	1.23	2.77	55.55	13.15	15.10	42.40	40.45	33.65	23.10	17.35	6.80
Site 6	Rai	A	0 - 10 cm	0.95	2.54	62.35	8.45	10.40	53.90	51.95	44.95	30.35	21.60	7.00
		Bw1	30 - 40 cm	1.03	2.69	61.75	11.60	13.85	50.15	47.90	41.75	33.60	14.30	6.15
Site 7	Ronga	A	0 - 10 cm	1.26	2.68	53.05	#DIV/0!	1.35	53.20	51.70	46.45	26.45	25.25	5.25
		B	30 - 40 cm	1.44	2.77	47.80	8.20	9.50	39.65	38.30	33.60	22.70	15.60	4.70
Site 8	Pelorus	A	0 - 10 cm	0.97	2.54	61.65	4.25	6.20	57.40	55.45	48.90	29.20	26.25	6.55
		BW1	25- 35 cm	1.14	2.69	57.55	10.05	11.70	47.60	45.85	40.90	34.35	11.50	4.95

Site 9	Ronga	A	0 - 10 cm	1.35	2.69	49.95	3.90	5.55	46.05	44.40	38.00	22.10	22.30	6.40
		B	25- 35 cm	1.35	2.76	51.05	12.80	14.75	38.25	36.30	29.45	16.85	19.45	6.85
Site 10	Rai	A	0 - 10 cm	0.95	2.58	63.25	5.70	7.85	57.50	55.40	48.90	29.35	26.05	6.50
		BW1	35 - 45 cm	1.08	2.73	60.50	20.50	23.90	40.00	36.60	29.05	19.30	17.30	7.55
Site 11	Pelorus	A	0 - 10 cm	0.98	2.55	61.65	6.60	6.05	58.30	55.60	48.30	31.40	24.20	7.30
			NONE	0.98	2.68	63.5	18.2	20.4	45.3	43.1	37.8	31.8	11.30	5.30
Site 12	Ronga	A	0 - 10 cm	1.17	2.65	55.60	2.35	4.55	53.35	51.05	44.20	22.70	28.35	6.85
			30 - 40 cm	1.36	2.75	50.60	12.65	15.65	37.90	34.95	28.05	16.70	18.25	6.90
Site 13	Rai	A	0 - 10 cm	0.96	2.53	62.05	4.50	7.15	57.55	54.90	48.20	31.80	23.10	6.70
		BW1	30 - 40 cm	1.05	2.70	61.25	9.35	11.85	51.90	49.40	42.20	34.05	15.35	7.20
Site 14	Ronga	A	0 - 10 cm	1.16	2.71	57.25	2.50	4.50	56.75	54.85	46.75	21.05	33.80	8.10
		C1	30 - 40 cm	1.45	2.80	48.10	8.25	9.80	39.90	38.30	32.45	23.40	14.90	5.85
Site 15	Pelorus	A	0 - 10 cm	0.95	2.56	62.70	8.05	9.75	54.65	52.95	45.40	27.30	25.65	7.55
		BW1	30 - 40 cm	1.15	2.69	57.15	10.45	11.90	46.70	45.25	40.40	32.60	12.65	4.85
Site 16	Rai	A	0 - 10 cm	0.99	2.53	60.65	3.05	5.30	57.60	55.35	48.25	31.65	23.70	7.10
		BW1	30 - 40 cm	0.99	2.66	62.85	18.40	21.20	44.45	41.65	34.70	30.25	11.40	6.95
Site 17	Ronga	A	0 - 10 cm	1.01	2.60	60.90	3.50	5.45	57.35	55.45	49.10	27.15	28.30	6.35
		B	30 - 40 cm	1.12	2.72	58.60	13.20	14.60	45.45	44.00	38.70	28.30	15.70	5.30