STAFF REPORT

TO:	Environment & Planning Committee
FROM:	Andrew Burton, Resource Scientist - Land
REFERENCE:	L213
SUBJECT:	**SOIL HEALTH MONITORING PROGRAMME - SOIL HEALTH SAMPLING 2009 - REPORT REP10-07-06 -** Report prepared for meeting of 1 July 2010

1. INTRODUCTION

The aim of this monitoring programme is to assist Council to collect and interpret information on soil health in the region, as required by the RMA 1991 for the purposes of State of the Environment reporting. The information will contribute to improved sustainable management by providing quantitative data to evaluate the risk to, and state of, the soil resource under intensive land use.

Monitoring of Soil Health in the Tasman District was initiated in 2000 with the collection of information at 10 sites as part of the Ministry of the Environment's "500 Soils Project". The sites selected were four pastoral (dairying), one market garden, two orchard and three rehabilitation (mining and gravels extraction) sites (Report: "Implementation of soil quality indicators for land in the Tasman region - a progress report for Year 1") In 2005 additional pastoral sites were sampled including one dairying and four sheep and beef (Report: "Soils quality sampling, Tasman District August 2005").In 2009 eight additional sites have been selected for monitoring. In conjunction with the aim of providing soil health data for each site, the information collected will be used to quantify the physical and chemical characteristics of soil types mapped in the recent soil mapping project Council has been carrying out in the Takaka Valley. Although this has influenced where sampling has been carried out it has not detracted from the aims or effectiveness of the soil health monitoring programme.

This report summarises the soil quality monitoring undertaken at these new sites.

2. METHOD

The 2009 programme includes eight sites in the Takaka Valley all situated on different soil types. Seven of the sites are on dairying and one on a small scale beef operation. Sample sites were determined in the field to ensure that sites selected are representative of the major soils, topography and land use/management of the area. The sites and their description are listed in Table 1 below.

Table 1

Site code	Soil type	Land use
TDC 09.16	Takaka	Pasture, dairying
TDC 09.17	Uruwhenua	Pasture, dairying
TDC 09.18	Anatoki	Pasture, dairying
TDC 09.19	Ikamatua	Pasture, dairying
TDC 09.20	Puramahoi	Pasture, dairying
TDC 09.21	Motupipi	Pasture, dairying
TDC 09.22	Pisgar	Pasture, beef
TDC 09.23	Hamama	Pasture, dairying

At each sample site, a site description and soil profile was completed and sampling carried out to assess the following basic soil properties:

1. Total Carbon
2. Total Nitrogen
3. Mineralisable Nitrogen
4. Soil pH
5. Olsen P
6. Bulk density
7. Macroporosity
8. Aggregate stability

These are the soil properties used in the “500 Soils Project” and the sampling protocols for these are found in Appendix 3.

In addition to these properties the volumetric water content at 5,10,100,1500kpa, and total recoverable arsenic, cadmium, chromium, copper, lead, nickel, zinc were collected.

The volumetric water content data is required to assist with irrigation management and will be used specifically by Council for irrigation water allocation purposes. Part V of the Tasman Resource Management Plan details the weekly allocation limit for consents using water for irrigation based on the water holding capacity of the soils to which it is applied. A recent addition, the heavy metal sampling, has been added to the monitoring programme due to the potential contamination risk associated with some past and present land use practises such as fertiliser application and disease control. For example, cadmium is a contaminant of super phosphate, facial eczema treatment contains high levels of zinc, and copper is used as a fungicide in orchards. Heavy metals accumulate in the soil hence even small inputs on a yearly basis may in the long term accumulate to detrimental levels.

The soil properties themselves do not measure soil quality; rather soil quality is a value judgement about how suitable a soil is for its particular land use. A group of New Zealand experts in soil science developed soil response curves for each of the soil properties, and established critical values or optimal ranges for the assessment of soil quality for the predominant Soil Orders under a number of different land uses. These critical values and optimal ranges are used to assess soil quality in this report.

3. RESULTS

3.1 Soil Chemistry

Total Carbon levels are an indication of organic matter content which is important for moisture and nutrient retention and for good soil structure. The issues relating to total carbon are soil organic depletion and carbon loss from the soil as a result of intensive land use. The sample results range from 4.08 to 7.58 mg/cm³ which all fall within the **“normal”** (4 - 9) range.

Total Nitrogen is an essential nutrient for plants and animals. Most nitrogen (N) in soil is within the organic matter fraction, and total N gives a measure of those reserves. Usually only a small fraction of the total N is immediately available for plant uptake (soluble inorganic nitrogen). While a variable proportion of the total nitrogen is potentially mineralisable to inorganic. In general, high total nitrogen indicates the soil is in good biological condition. However, very high total nitrogen contents increase the risk that nitrogen supply may be in excess of plant demand, and ultimately lead to leaching of nitrate to groundwater. The results for the eight sites range from 0.39 to 0.69 mg/cm³ of Total Nitrogen. These all fall into the **“normal”** (0.35 - 0.65) **to “ample”** (0.65 - 0.7) range.

Mineralisable Nitrogen (anaerobic) levels indicate the readily decomposed organic N. Not all the organic matter N can be used by plants; soil organisms change the N to forms that plants can use. Mineralisable N gives a measure of how much organic N is available to the plants, and the activity of the organisms. The issues are N build-up in soils, reserves of plant available N and the potential for N leaching at times of low plant demand. The results range from 147 to 222 mg/Kg of mineralisable Nitrogen. These all fall in the **“adequate”** (100 - 200) **to “high”** (200 - 250) range well above the lower critical limit of 50mg/kg and below the upper critical limit of 250mg/kg.

Olsen P levels indicate the level of plant available phosphorus and general fertility of the soil. Phosphorus (P) is an essential nutrient for plants and animals. Plants get their P from phosphates in soil. Many soils in New Zealand have low available phosphorus, and P needs to be added for agricultural use. The issues associated with P levels are the possible depletion or “mining” of the soil nutrient reserve or excessive fertilizer use and its potential for its loss to waterways which contributes to eutrophication risk. The results collected range from 35 to 73 units. These all fall within the **“adequate”** (20 - 50) to **“ample”** (50 - 100) range. The lowest result, 35, was measured at TDC 09-22 which is the beef unit and it likely reflects the less intensive style of farming compared to all the other sites which are used for dairying.

pH is a measure of soil acidity. Most plants and soil animals have an optimum pH range for growth. Indigenous species are generally tolerant of acid conditions but introduced pasture and crop species require a more alkaline soil. The issues associated with pH levels are that some sites may fall outside the favourable pH range for some plant species. Also some heavy metals may become soluble and bioavailable at certain pH ranges. The results range from pH 5.43 to 6.49. Six of the eight sites fall within the “**optimal**” range (pH 5.5 - 6.3) with two falling just outside but still well within the critical limits for pastoral farming on these soils which are: pH5 at the lower end and pH6.6 at the higher end.

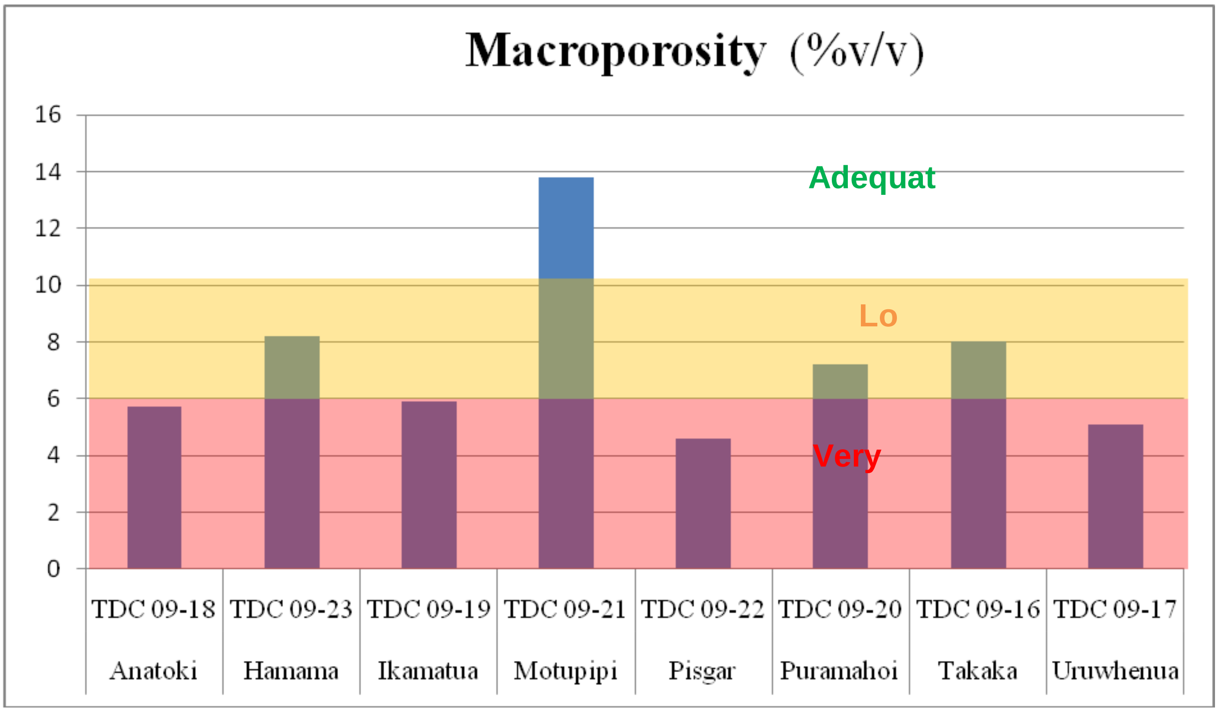
Discussion on Soil Chemistry

All soil chemistry properties fell within the required range for healthy soils and reflect a history of fertiliser application and sustainable soil/pasture management. Some of the sites that are at the upper end of the scale especially those for P and N need to be managed such that they do not reach a state where they start to export surplus nutrient to surface water ways. This is not an issue yet but something to consider for the future.

3.2 Soil Physical Characteristics

Bulk Density levels indicate the level of soil compaction. Compacted soils restrict water or air penetration into the soil profile which restricts drainage and root growth. This in turn has the potential to increase surface water run-off and nutrient losses. The results range from 0.8 to 1.05mg/m³. These all fall within the **"adequate"** range (0.8 to 1.2)

Macroporosity levels also indicate the level of soil compaction and aeration. Macropores are important for air penetration into soil, and are the first pores to collapse when soil is compacted. This can adversely affect plant growth due to poor root environment, restricted air access and N-fixation by clover roots. The results range from 4.6 to 13.8 %v/v as indicated in the chart below.



Half of the results fall within the "very low" category (0 - 6), three within the low category (6-10) and only one fell within the adequate range (10 - 30). The lowest four results fell below the critical limit of six.

Aggregate Stability is a measure of how resistant soil crumbs are to breakage. A stable "crumbly" texture lets water quickly soak into soil, does not dry out too rapidly, and allows roots to spread easily. Measured levels were all very similar, ranging from 2.45 to 2.59. There is currently no soil quality ranking for aggregate stability under a grazing regime. However scientific opinion indicates that an aggregate stability > 2 mm mean weight diameter is considered necessary for optimal soil quality for both production and environmental parameters.

Discussion on Soil Physical results:

Macroporosity was the only parameter where measurements indicated that there were issues. Four of the eight results fell below the critical limit. Low macroporosity values indicate a degree of compaction and possibly pugging. As all sites are used for pastoral farming, and have been for many years, the low macroporosity values will be primarily due to the livestock and soil interaction. Animal grazing and trampling causes soil deformation through soil compaction, and also through soil pugging.

The effect of soil compaction is to reduce porosity, restrict air and water movement, and increase density and resistance. The volume of large connected drainage and aeration pores (macropores) is particularly prone to reduction from soil compaction by animals. Typically, soil compaction occurs at soil moisture contents less than for pugging, although both processes may occur over a range of soil moisture values. There are several comprehensive reviews on soil compaction related to pastoral grazing systems. It is commonly accepted that through reduction in the macroporosity, intensively managed grazing systems can result in reductions in pasture yield, biodiversity, increased soil erosion and surface water runoff and reduced soil weight-bearing capacity. Indications are that pasture production reduction may result as a consequence of the low macroporosity at all but one of the sites measured in 2009.

Bulk density is another soil physical property used to assess soil compaction. Measurements indicate that bulk density at all the sites were adequate.

The profile descriptions completed at each of the sites can also give an indication of possible issues relating to compaction and associated drainage and permeability attributes. All descriptions indicate the soil profiles were well drained and had moderate or moderate to rapid permeability. Only in the Takaka silt loam profile were mottles observed. These were only found in the A horizon (0-8cm). Soil mottling can indicate a compaction or pugging problem. All sample sites were assessed as having moderate to good pasture condition and signs of old or new pugging were minimal.

The bulk density, soil profile and pasture cover observations would indicate that, at the majority of sites, compaction is not significant. The macroporosity results would indicate otherwise and as it is the more sensitive of the indicators used it should not be ignored.

Landcare Research operates a web-based decision support system called SINDI which uses the same seven soil indicators as used in this programme. It also uses the same target ranges. It combines macroporosity and bulk density results to give an overall indication of “soil physical quality”. Using SINDI to indicate the overall physical quality of the soil at the sites measured gave five “excellent” and three “okay” results. This is despite the low macroporosity readings at the majority of sites.

3.3 Trace Element Analysis

A deficiency or an excess of trace elements in soil can have a major bearing on soil health despite their low concentrations. Some trace elements are essential micronutrients for plants and animals. Others are not. However, both essential and non-essential elements can become toxic at higher concentrations.

A suite of the most common environment-impacting elements arsenic, chromium, cadmium, copper, lead, nickel and zinc were measured at each site. These trace elements can accumulate in soils as a result of common agricultural and horticultural land use activities and are most likely to have a negative effect on soil quality.

The Ministry for the Environment’s “Environmental Guideline Value (EGV) database” has been used to provide guidance as to which soil guideline values to use for interpretation of the data gathered. The guideline is used to assess if values for specific trace elements are at concentrations in soils that are likely to have a negative effect on soil quality. These effects specifically include factors such as soil microbial function, soil invertebrate populations, phytoxicity, animal health, the protection of groundwater and the protection of human health.

The results of the trace element tests are presented in Table 2 below.

Table 2: Trace Element levels (total recoverable) of Sites Sampled in the Tasman District: 2009

Site Code	**Land Use**	**Soil Type**	**Arsenic** mg/kg dry wt	**Cadmium** mg/kg dry wt	**Chromium** mg/kg dry wt	**Copper** mg/kg dry wt	**Lead** mg/kg dry wt	**Nickel** mg/kg dry wt	**Zinc** mg/kg dry wt
TDC 09-16	dairying	Takaka	**8.9**	**0.55**	**66**	**30**	**15**	**48**	**76**
TDC 09-17	dairying	Uruwhenua	**7.1**	**0.62**	**36**	**17**	**12**	**11**	**37**
TDC 09-18	dairying	Anatoki	**5.2**	**0.60**	**17**	**13**	**12**	**17**	**35**
TDC 09-19	dairying	Ikamatua	**11**	**0.73**	**48**	**23**	**11**	**30**	**86**
TDC 09-20	dairying	Puramahoi	**5.3**	**0.56**	**43**	**27**	**19**	**23**	**130**
TDC 09-21	dairying	Motupipi	**5.5**	**0.66**	**32**	**27**	**12**	**24**	**78**
TDC 09-22	beef	Pisgar	**7.9**	**0.33**	**46**	**16**	**17**	**22**	**66**
TDC 09-23	dairying	Hamama	**11**	**0.52**	**85**	**20**	**12**	**56**	**54**
Guideline values adapted from NZWWA (2003)			***20***	***1***	***600***	***100***	***300***	***60***	***300***

Discussion on Trace Element Analysis:

Arsenic, Chromium, Copper, Lead, Nickel and Zinc levels at all sites fall well under the NZWWA limits for each heavy metal.

Cadmium levels range from 0.33 to 0.73mg/kg with an average of 0.57mg/kg. The lowest level was recorded on the beef block. The dairying sites range from 0.52 to 0.73mg/kg. New Zealand has a national average baseline (i.e. the “natural” background level in soils) value for cadmium of 0.16 mg/kg which is consistent across all regions and soil types. The current national average concentration of cadmium from soils used for agricultural production is 0.35 with a range of 0-2.52 mg/kg.

The Canadian Environmental Quality Guidelines (CCME 2002) provide the only assessment levels for agricultural soils. 1.4 mg/kg is set as an upper limit for the soil cadmium content. The NZWWA (2003) limit is 1 mg/kg. Although the measured levels are below the guideline limits they are above what is considered typical background levels. The source of rising cadmium levels is primarily due to repeated applications of phosphate fertilizer such as super phosphate containing cadmium as a trace impurity. Cadmium accumulation in agricultural soils is recognized as an emerging issue by government and industry. The “Cadmium Working Group” was recently been set up by the Ministry of Agriculture and Forestry to produce a national strategy to manage the cadmium issue.

4. SUMMARY

The 2009 sampling of eight new farm sites in the Tasman region found the soils to be in good condition. Macroporosity was the only indicator that fell outside the optimal range at a number of sites. Other indicators of soil physical quality did not indicate the prospect that there are significant issues with soil compaction. On a national scale low macroporosity levels are emerging as a significant issue particularly on dairy farms. As a consequence soil compaction and pugging issues along with the required preventative and remedial actions are being well publicised by the dairy industry. It will be worth paying particular attention to any trends that may indicate negative trends regarding macroporosity at a local level. Other soil quality indicators were all within their accepted critical ranges.

Concentrations of trace elements were all under the guideline limits used although we are aware of the prospect that further intensification may lead to the risk of elevated cadmium levels in pasture soils which may then limit their productive potential.

5. RECOMMENDATION

That this report be received.

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6. REFERENCES

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7. APPENDIX

7.1 2009 Soil Physical and Chemical Characteristics Data

Table 3: Soil Physical Characteristics of Sites Sampled in the Tasman District: 2009

Site Code	**Land Use**	**Soil Type**	**Bulk Density** mg/m^3	**Particle Density** mg/m^3	**Total Porosity** % v/v	**Macro Porosity (-10kPa)** % v/v	**Readily Available Water** % v/v	**Total Available Water** % v/v	**Aggregate Stability** MWD mm
TDC 09-16	dairying	Takaka	1	2.59	61.3	8.0	9.7	37.9	2.50
TDC 09-17	dairying	Uruwhenua	1.02	2.46	58.7	5.1	8.9	29.7	2.58
TDC 09-18	dairying	Anatoki	1.1	2.5	56.1	5.7	9.5	31.8	2.46
TDC 09-19	dairying	Ikamatua	1.02	2.54	59.9	5.9	8.0	32.2	2.59
TDC 09-20	dairying	Puramahoi	.97	2.51	61.3	7.2	10.2	33.6	2.45
TDC 09-21	dairying	Motupipi	.8	2.54	68.4	13.8	11.2	33.5	2.25
TDC 09-22	beef	Pisgar	.97	2.51	61.3	4.6	11.4	30.9	2.52
TDC 09-23	dairying	Hamama	1.05	2.53	58.7	8.2	10.3	28.6	2.59

Table 4: Soil Chemical Characteristics of Sites Sampled in the Tasman District: 2009														
Site Code	**Land Use**	**Soil Type**	**Total C mg/cm^3**	**Total N mg/cm^3**	**C:N Ratio**	**AMN[1]**	**Olsen P Φg/cm^3**	**pH**	**Base sat. %**	**CEC cmol/10^3/cm^3**	**Exchangeable Cations cmol/10^3/cm^3**			
											Ca	Mg	K	Na
TDC 09-16	dairying	Takaka	4.08	0.39	10.5	147	59	5.80	62	15.0	7.85	1.08	0.28	0.07
TDC 09-17	dairying	Uruwhenua	7.58	0.64	11.8	180	73	5.73	54	26.8	11.5	1.63	1.27	0.09
TDC 09-18	dairying	Anatoki	5.64	0.51	11.1	163	61	5.54	52	20.5	8.53	1.30	0.85	0.09
TDC 09-19	dairying	Ikamatua	6.71	0.56	12	176	51	5.61	45	23.3	8.94	1.01	0.46	0.10
TDC 09-20	dairying	Puramahoi	6.44	0.61	10.6	222	41	5.83	67	23.0	11.5	2.31	1.48	0.19
TDC 09-21	dairying	Motupipi	7.20	0.69	10.4	216	46	6.15	70	31.4	17.6	3.63	0.46	0.17
TDC 09-22	beef	Pisgar	6.78	0.60	11.3	185	35	6.49	83	27.3	18.5	3.28	0.67	0.25
TDC 09-23	dairying	Hamama	5.73	0.51	11.2	148	48	5.43	46	22.5	8.19	1.17	0.99	0.11

1 AMN = anaerobically mineralisable. (mg/Kg)

7.2 Sampling and Analytical Methods

At each site a 50 m transect is laid out. For chemical analysis 25 individual soil cores 2.5 cm in diameter to a depth of 10cm are taken every 2 m along the transect. The cores are bulked and mixed in preparation for chemical analyses. Analysis is carried out at the Landcare Research soil chemistry and soil physics laboratories in Palmerston North.

For the physical analyses three undisturbed soil samples are also obtained from each site at 15, 30 and 45 m intervals along the transect by pressing steel liners 10 cm in width and 7.5 cm in depth into the top 10 cm of soil. Analysis is carried out at the Landcare Research soil chemistry and soil physics laboratories in Palmerston North.

For the aggregate stability measure take triplicate samples from the same transect positions as the soil cores (15-, 30- and 45 m). The sample consists of a vertical block of soil 10 cm deep, 10 cm wide and 1-3 cm thick from a fresh soil face. Analysis is carried out at the Plant and Food Research laboratories at Lincoln.

The trace element sampling procedure is a replicate of that carried out for the soil chemical analysis with 25 individual cores bulked. Analysis is carried out at RJ Hills Laboratory in Hamilton.

Recommended procedures for soil physical and chemical analyses are:

- **Total C and N -** Analyses using high temperature combustion methods
- **Soil pH** - measured by glass electrode in a slurry of 1 part by weight of soil to 2.5 parts water.
- **Olsen P** - Extraction by shaking for 2 h at 1:20 ratio of air-dry soil to 0.5 M NaHCO3 at pH 8.5, filtered, and the phosphate concentration measured by the molybdenum blue reaction using Murphy-Riley reagent .
- **Potentially mineralisable N** - estimated by the anaerobic incubation method. Moist soil is incubated under waterlogged condition (5 g equivalent dry weight with 10 ml water) for 7 days at 40□C. The increase in ammonium-N extracted in 2 M KCl over the 7 days gives a measure of potentially mineralisable N.
- **Water release** (used to calculate porosity) - Calculated from drainage on pressure plates at specific tensions (Gradwell and Birrell, 1979).
- **Dry bulk density -** Measured on a sub-sample core of known volume dried at 105°C (Gradwell and Birrell, 1979). The weight of the oven-dry soil expressed per unit volume, gives the bulk density. The bulk density is also needed to calculate porosity.
- **Particle density -** Measured by the pipette method as described by Claydon (1989). The particle density information is needed to calculate total porosity (see below).

- **The total porosity -** Calculated from the formula: $S_t = 100[1- (p_b/p_p)]$ (Klute, 1986), where S_t is total porosity, p_p is the particle density and p_b is the dry bulk density.

- **Macroporosity -** is calculated from the total porosity and moisture retention data: $S_m = S_t$ - where S_m is macroporosity, and is the volumetric water content at -10 kPa tension (Klute, 1986).

- **Aggregate stability** is calculated from the mean weight diameters of aggregates remaining on 2 mm, 1 mm and 0.5 mm sieve after wet sieving.

- **Trace elements -**use the total recoverable trace element extraction method - US EPA 200.2