

**Background concentrations of  
selected trace elements in  
Canterbury soils**

**Addendum 1: Additional samples  
and Timaru Specific background  
levels**

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Report No. R07/1/2

ISBN: 978- 1-86937-699-4

Report prepared by  
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February 2007





**Report R07/1/2**  
**ISBN 1-86937-648-2**

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# **REPORT**

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## **ENVIRONMENT CANTERBURY**

**Background concentrations of  
selected trace elements in  
Canterbury soils  
Addendum 1: Additional samples  
and Timaru specific background  
levels**

**Report prepared for:**  
ENVIRONMENT CANTERBURY

**Report prepared by:**  
TONKIN & TAYLOR LTD

**Distribution:**  
ENVIRONMENT CANTERBURY 2 copies  
TONKIN & TAYLOR LTD (FILE) 1 copy

**February 2007**

**Job no: 50875.003**

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## 1 Introduction

Tonkin and Taylor is pleased to present this report detailing the methodology and results of additional investigations into the background concentration of selected trace elements in Canterbury soils. This study is addendum 1 to Phase II of the *Background concentrations of selected trace elements in Canterbury soils* project being carried out by Environment Canterbury (ECan), and should be read in conjunction with that report (Tonkin & Taylor 2006). The aim of this addendum is to provide additional data for the existing regional trace elements database, as well as data specific to the Timaru urban area. This data was obtained through additional field sampling and laboratory analysis undertaken in January 2007 (regional samples and Timaru urban samples) and in May 2007 (additional Christchurch urban samples).

The work was undertaken in accordance with our proposals dated 8 December 2006 and 10 April 2007.

## 2 Previous reports

ECan has commissioned three previous reports investigating the background concentration of trace elements in the region. The first two reports reviewed existing information and made recommendations for a sampling-based study. The latest report detailed the results of a sampling based study to ascertain background concentration data for a range of major Canterbury soil types:

The reports completed to date are as follows:

- Landcare Research NZ Ltd (1996). Assessment of background concentrations of selected determinands in Canterbury Soils.
- URS NZ Ltd (2005). Sampling Methodology for determining Background Soil Quality in Canterbury.
- Tonkin and Taylor Ltd (2006) Background concentrations of selected trace elements in Canterbury soils

The soil group locations and background levels established in the 2006 study have been included as layers in ECan's online GIS software (<http://www.ecan.govt.nz/ECanMapping/viewer.htm>).

## 3 Background

ECan maintains a Listed Land Use Register (LLUR) to manage information it holds about contaminated land and sites that have accommodated land uses or activities that have the potential to cause contamination.

Sites are placed on the Register if the site has been, or is being used for activities that are likely to have caused contamination. These potentially contaminating activities are contained within the Hazardous Industries and Activities List (HAIL) (MfE, 2004) and relate to activities where hazardous substances are used, stored and disposed. Sites are identified and placed on the register based on a range of documented evidence of site use. Prior to confirmation of the landuse by the site owner, a site is entered in the database as 'unverified'. Once the site's historical and current landuse have been checked, the site is

classified as 'verified'. If sufficient investigative information is available, i.e. from a comprehensive site investigation, it can be given one of three status levels:

- Contaminated;
- Managed/ remediated, or
- Not contaminated.

In order for a site to be classified as not contaminated in the LLUR, a suitably detailed site assessment must indicate that no contaminants associated with past or current land uses are present on the site, or that the site has been remediated to, or below, background levels for selected contaminants. As certain trace elements are naturally present in soil, information on background levels of these trace elements in soils is necessary when assessing whether a site has been contaminated and to set achievable remediation targets.

Information on background levels for trace elements in the region has been supplied by the initial study (Tonkin and Taylor, 2006) which developed background levels for regional soils and the Christchurch urban soils. The aim of the project is to provide additional data to add to the existing database for regional and Christchurch soils as well as developing specific background levels for Timaru urban soils.

## 4 Scope of works

The full scope of work is detailed in the original proposal and the contract for services. A summary of the scope for the project is as follows:

- Analyse the current distribution of samples and identify gaps that require sampling;
- Undertake a brief review of sample locations to assess likely suitability of identified sample sites;
- Undertake sampling in accordance with the method used for the original fieldwork and detailed in the report (Tonkin and Taylor, 2006);
- Dispatch samples to Hill Laboratory for analysis;
- Incorporate the new results into the original data set. Reanalyse all analytical results for the soil groups to produce the summary non-parametric statistics as detailed in Section 5.3 of the original report and new background levels;
- Produce summary non-parametric statistics and new background levels for Timaru urban area, and
- Produce a short report summarising the additional sampling, the new results and modifications to the existing background levels and any further recommendations.

## 5 Review of existing sample distribution

To identify which soil groups would most benefit from additional sampling in this round, the current sample distribution and data quality was reviewed. The following points resulted from this review:

- The Recent soil group has high variability, and is a prevalent soil group commonly associated with built up areas. Consequently additional data for this group would be highly desirable.
- The Yellow Brown Stony soil group covers a large area of the plains, and had a relatively low sample density. Landuse of this soil group is predominantly

agricultural, however a number of urban areas are located on or near YBST soils. Additional samples in this soil group are considered a priority.

- The concentrations measured within the Christchurch City were, in most cases, higher than the regional data. Elevated concentrations in the other major urban centres in Canterbury are likely. As Timaru is the second largest town in the region, and as marginal land is beginning to be developed, a local background should be developed for Timaru.
- As the background levels will most often be used for sites within the Christchurch urban area, additional samples in the most common soils, gley, yellow brown sand and recent soils types, would increase the robustness of the background level predictions.

## 6 Methodology

To retain consistency with the initial study, the same sampling methodology was used for this addendum. The only modification was that the deeper 0.5m soil samples were not collected during this study. A summary of the methodology is contained in the following sections. For more detail please refer to the original report.

### 6.1 Soil grouping

The soil groupings and GIS based maps created in the original study were used for this investigation. For details of why the soil groups were created, the basis for the groupings, the methods used and definitions of all soil groups please refer to the main report (Tonkin and Taylor, 2006).

Soil maps of the regional sample areas as well as the Timaru Urban sample area are included in Appendix A. These maps also show the sample locations.

### 6.2 Site selection

Where possible, sample sites were chosen on public land (as defined by GIS layers provided by ECan) as public land is less likely to have been extensively modified, sprayed or fertilised with chemicals that may affect the results. In addition, sampling on public land reduces access issues. All samples in this additional sampling round were on publicly owned property.

A flow chart was developed in the original study to formalise the process of site selection. The flow chart is displayed in Appendix C of the main report (Tonkin and Taylor, 2006).

Where possible, the additional samples were distributed across the geographical spread of the soil group to account for any local variation and provide good spatial coverage.

If there was some uncertainty in the sites selected, an alternative was also chosen in case field verification of the initial site proved it was unsuitable.

Maps of the additional sample locations are provided in Appendix A and B.

### 6.3 Sample collection

The sample collection of Timaru urban samples and additional regional samples was carried out by an environmental engineer between the 22<sup>nd</sup> and the 23<sup>rd</sup> of January 2007. Additional Christchurch urban samples were collected by an environmental scientist between the 3<sup>rd</sup> and 10<sup>th</sup> of May 2007.

The sampling collection method used was the same as used for the original sample set. A brief discussion of the method is included below, if more detail is required please refer to the original report.

### 6.3.1 Sample coding

Prior to going out in the field, labels for each sample site were printed. Each site was identified on the label with a unique code. The code was in the following form:

Example: AS\_YBST\_1\_sample 1

The AS designates that the sample was part of the addendum sampling round. These first two letters could also be TIM to designate Timaru samples and MPU indicates the sample was the additional Christchurch urban samples (the M denotes metals the P means the samples was also analysed for PAH compounds (see Tonkin and Taylor, 2007) and the U denotes it as an urban sample). The YBST identifies the soil group, in this example yellow brown stony. The '1' identifies the sample within that soil group, and the 'sample 1' identifies the sub sample within the site. Each sample label also included the date, job number and depth.

### 6.3.2 Field verification of site suitability

Upon arrival at each pre-selected site, a walkover inspection was carried out to ascertain if any modifications had occurred to the site and to identify any potential sources of contamination. If the walkover indicated the site was suitable, a small trial pit was hand dug with a stainless steel spade to 0.5m. The pit was inspected to further confirm the soil column was not disturbed or modified. If the pit revealed a suitable profile the soil sequence was logged and sampling began, otherwise the site was discarded and an alternative site used.

### 6.3.3 Sample collection

Once the site was considered suitable, a standardised sampling protocol was carried out. The following outlines the steps carried out in sample collection:

- An 80m by 80m square was divided into four equal quadrants (with the trial pit located in one of these quadrants). Sample locations were selected randomly within the quadrants (see Figure 1).
- Four samples were taken at each location at a depth of 0-015m, three using a hand auger and the fourth a stainless steel trowel from within the pit.
- All samples were placed directly into pre labelled zip lock plastic bags (or glass jars for the Christchurch urban samples) and then immediately into a chilly bin.
- A digital photograph was taken of each pit including one of a sample label. The pit was logged for basic soil characteristics i.e. layering, texture, colour etc as per standard soil classification techniques and a GPS co-ordinate taken.
- At the end of each day, the shallow (150mm) samples were entered onto a chain of custody form and couriered to Hill Laboratories upon return to Christchurch.

The brief soil logs are contained in Appendix C.

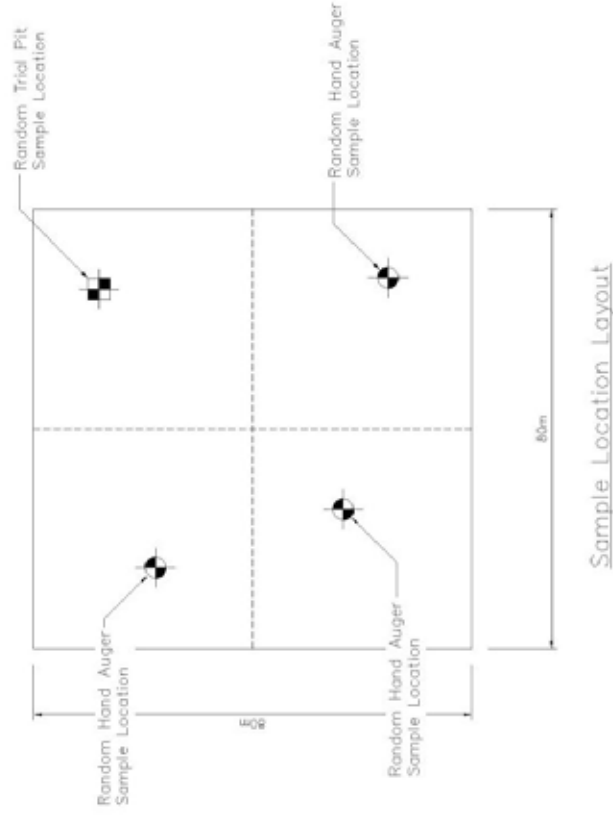


Figure 1 – Sample collection layout

#### 6.3.4 Field quality assurance and quality control

Due to the numbers of samples being taken, a risk of sampling error and cross contamination between samples did exist, either during collection, labelling or dispatch. The following steps were taken to reduce the risks of sampling error.

- Having a well establish sampling method developed for and proven to work in the initial study;
- Pre-labelling all sample bags/jars prior to arriving at the site;
- Photographing the sample labels, if a labelling error did occur the photographs could be referenced against the site photos and the error corrected;
- Upon receipt of the job cover sheet from the laboratory, all samples were cross checked against the chain of custody to ensure samples were received and recorded correctly;
- Following the collection of samples from each location, all sampling equipment was cleaned by brushing and wiping off all soil, and triple rinsed with filtered water to remove any remaining trace of soil. As the Christchurch urban soils were also being analysed for PAH compounds (see Tonkin & Taylor 2007 for details), sampling equipment used for these soils was also washed with Decon 90 during sample collection.

#### 6.4 Laboratory analysis

Samples were analysed for the same suite of inorganic elements and soil properties as the original investigation. The analytes investigated are as follows:

- |           |            |             |
|-----------|------------|-------------|
| • Arsenic | • Chromium | • Manganese |
| • Boron   | • Copper   | • Mercury   |
| • Cadmium | • Lead     | • Nickel    |

- Zinc

Total organic carbon, Nitrogen, fluoride and pH were also analysed for use in other ECan projects, and are not discussed further in this report. However, these soil properties were not analysed for in the Christchurch urban samples.

Hills Laboratories were contracted to carry out the analysis. The four samples from each site were sent to the lab where they were composited to form one sample. This composite sample was analysed for selected determinands using Hill Laboratories standard methods. One set of samples (MPU YBS S4, MPU RE S10 and S11) were mistakenly analysed at a screen level. As all results (aside from one cadmium result) were above detection limits, reanalysis at trace level would have provided no additional benefit and was not undertaken.

Details of the methods of analysis and detection limits are provided in Appendix D along with the full laboratory transcript.

## 6.5 Distribution analysis

Based on the previous study, the variability of the data, and small sample size do not merit the use of parametric based statistics. Due to this, further distribution fitting was not included in the scope of works and no distribution analysis was undertaken on the new data sets. Instead, and to be consistent with the main report, the same non-parametric summary statistics were produced.

## 6.6 Comparisons with existing data

Results from the additional samples were compared with the existing data using box and whisker plots. Due to the small number of samples no additional ANOVA analysis was carried out between the new data sets, or between the soil groups. A discussion of each sample population is contained in sections 7.1.1 to 7.1.3.

## 6.7 Detection and analysis of outliers

An outlier by definition is ‘an atypical, infrequent observation; data points which do not appear to follow the characteristic distribution of the rest of the data. In this case, an outlier may be a result of natural variation or anthropogenic contamination. To avoid use of outlying data from a site, which may produce anomalous results, skew the sample set and render it unrepresentative for the true population, the outliers must be identified.

To identify outliers in the data set, visual inspection of the data on probability-probability (PP), normal probability (NP) and box and whisker plots were used. Given the small sample sizes, no distinction was made between an extreme and outlier value, and within this report they are both termed outliers.

The outliers indicated by the box and whisker plots were further investigated on the PP and NP plots, and visual inspection of the data. If the outlier in question originated from a sample with few replicates, comparisons were made with concentrations in other similar soil groups. If all the plots suggested the data point was indeed an outlier, it was tagged as an outlier and identified in the data set.

A discussion of the outliers present and their assessment is contained within sections 7.1.1 to 7.1.3.

## 7 Results

The results from the laboratory analysis were compiled and sorted into the relevant soil groupings. Appendix E contains the YBST, RE and the Christchurch and Timaru Urban results. All statistical analysis was carried out in Statistica 6, and the box plots used for comparative purposes are contained in Appendix E. The following sections discuss the results, the outliers and comparisons with the existing data.

### 7.1.1 Christchurch urban samples

In general, this recent round of samples returned results that were typically higher than the existing results. For the recent soil type with four additional samples, the new data also typically showed a greater range than the original sample data. The Yellow Brown Sand sample was within range, or below the range of the original sample data. The single gley sample was generally to the range of existing data, however As, Cr, Hg and Ni concentrations were found to exceed the existing data range.

The original Christchurch urban results did not contain any outliers. Reassessment of the Gley, Recent and Yellow Brown Sand data set (including the original data) using box plots (Appendix E) indicated the following potential outliers:

Gley	Copper, lead and zinc (all from sample MPU GY S6)
Recent	Arsenic and Zinc (both from one sample MPU RE S7)
Yellow Brown Sand	No outliers

Inspection of the probability plot and comparison with regional data and other published studies (URS, 2003 and ARC, 2001) indicated that only the lead result for MPU GY S6 was likely to be an outlier. All further calculations did not include the MPU GY S6 lead result. However, the result is included in brackets in the final background concentration tables. All other data points have been retained within the data set.

### 7.1.2 Regional YBST samples

The new set of YBST data (four samples) is generally within range of the existing data set, although typically had higher median values for the elements analysed. One outlier was indicated by the box and whisker plot for boron and mercury and relates to samples from the original data sets. Inspection of PP and NP plots of the larger data set, and comparison with other soil ranges indicated that the data points are not outliers. These data points have been retained in the dataset as in the original study.

### 7.1.3 RE regional samples

Like the YBST data, the new RE sample data is generally similar to the existing data but typically has higher median values for the elements analysed.

The box plots indicated that strong outliers were present in the copper and lead (AS RE S2) RE dataset. A duplicate sample (AS RE S2b) had also been taken at the site, and results for the duplicate sample were not elevated. Due to the abnormally high results, and the conflict with the duplicate, the lab was asked to re-run the analysis. Reanalysis results were still high for copper and lead but not consistent with the original results. This indicated that concentrations may not be consistent between sub-samples.

All sub-samples from AS RE S2 were analysed to investigate the discrepancy. Results from this analysis showed that one sub-sample was significantly elevated. Therefore the original result was discarded and the duplicate sample was used in the data set.

For comparison with the field duplicate, a composite value for AS RE S2 was calculated from the three remaining sub-samples. This is discussed in Section 8.1.

Inspection of box and whisker, PP and NP plots for the entire data set revealed the following:

- Outliers from the initial data set remained for boron and manganese.
- The maximum values for arsenic and cadmium were identified as outliers in the original report. These are no longer classified as outliers and are included in the data set.
- The maximum value for lead (from the new data) appears to be an outlier on the box plot. However comparison with other soil groups and normal probability plots indicates that it is not likely to be an outlier and should be retained in the data set.

#### **7.1.4 Timaru urban samples**

All five Timaru urban sample sites were in the YGE soil group, and for comparative purposes they were compared with the regional soil group data for the YGE soil type. The Timaru data set was generally similar to the regional data, but had slightly elevated results for some elements, specifically lead and copper. The box plots used for these comparisons are included in Appendix E.

The box plots indicated that four outliers (arsenic, nickel, mercury and zinc) were present in the data set. Comparisons with regional data, Christchurch urban data, and plotting of probability plots confirmed outliers for arsenic and nickel, the suspected outliers for lead and mercury were unlikely to be so and were retained in the data set.

The arsenic and nickel outliers (TIM YGE S5 and TIM YGE S3 respectively) were retained in the data set, but the individual outlier results were excluded from the background level calculations. As for the previous study, the outlier values are indicated on the background level tables in brackets.

## **8 Proposed background levels**

The same method of establishing background concentrations from the data used in the original investigation was used for this study. The method and justification are contained within the original report (Tonkin and Taylor, 2006) and a brief description of each level is as follows:

Level 1 Background: The maximum recorded concentration in the data set (excluding outliers, which are indicated in brackets)

Level 2 Background: The maximum recorded concentration in the data set plus ½ the interquartile range (excluding outliers, which are indicated in brackets)

The Level 1 background concentrations are contained in Table 1, and the Level 2 background concentrations are presented in Table 2.

**Table 1: Proposed level 1 background levels (all results in mg/kg)**

Soil Group	No. Samples	B	Mn	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn	
Regional	BCG/BGL	4	20.0	1780	5.1	0.20	(110.1)	(48.9)	0.04	(158.6)	20.7	116.0
	Gley	6	8.0	758	8.7	0.24	16.8	15.5	0.06	13.4	17.8	65.6
	Integrade	8	6.0	573	6.1	0.12	24.5	15.2	0.12 (0.6)	15.3	(133)	(134)
	Organic	3	7.0	114	2.9	0.34	13.8	18.4	0.1 (0.35)	7.2	25.9	53.5
	Recent	18	8(29)	536(1210)	11.5	0.18	20.8	18.8	0.09	19	37.4	86.5
	Rendzina	4	41.0	372	36.90	0.31	26.4	9.5	0.05	15.9	16.7	57.4
	Saline gley recent	4	19.0	251	6.8	0.09	13.2	12.2	0.07	9.6	44.4	47.3
	Yellow brown sand	4	9.0	1110	3.4	0.06	11.0	7.1	0.04	8.7	31.9	50.7
	Yellow brown stony	14	6.0	651.0	5.8	0.1	18.3	10.2	0.1	12.8	18.7	64.0
	Yellow grey earth	15	5.0	877	4.6	0.11 (0.18)	15.6	11.5	0.10	11.6	18.8	62.4
	Yellow Brown Earth	2	5.0	489	4.2	0.04	18.9	10.1	0.09	16.1	11.9	43.1
	Gley	6	6.0	602.0	10.6	0.2	18.5	23.3	0.1	15.6	34.9(127)	138.0
Organic	2	7.0	310	13.2	0.11	12.4	13.3	0.18	11.7	40.9	63.3	
Recent	8	7.0	548.0	15.3	0.2	19.0	17.7	0.1	16.6	101.0	149.0	
Saline Gley Recent	2	20.0	355	7.5	0.06	22.1	10.2	0.08	14.1	31.2	87.7	
Yellow Brown Sand	4	5.0	336.0	5.6	0.1	15.4	8.8	0.1	11.7	22.3	54.9	
YGE	5	5	562	3.3(11.9)	0.11	12.4	13.1	0.12	8.6(22.4)	56	122	

Table 2: Proposed level 2 background levels (all results in mg/kg)

Soil Group	No. Samples	B	Mn	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Regional	BGC/BGL	4	22.0	2000	6.5	0.24	(124.5)	36.9	37.1	40.5	129.1
	Gley	6	8.9	889	11.0	0.28	19.3	16.425	16.1	19.3	77.1
	Intergrade	8	6.5	707	7.0	0.14	25.9	16.3	0.07 (0.13)	16.4	30.3
	Organic	3	7.5	126	3.1	0.36	15.8	21.3	0.17 (0.42)	7.6	30.0
	Recent	18	9(30)	594.5(1268.5)	12.58	0.19	22.70	20.30	0.11	20.70	40.96
	Rendzina	4	43.1	434	43.48	0.37	29.6	10.4	0.06	17.6	20.3
	Saline gley recent	4	22.1	295	8.8	0.11	14.6	14.7	0.08	10.6	53.1
	Yellow brown sand	4	11.0	1245	3.5	0.08	12.4	7.9	0.05	9.6	39.0
	Yellow brown stony	14	6.50	721.4	6.35	0.14	19.89	11.68	0.07	13.91	19.75
	Yellow grey earth	15	5.5	1031	4.9	0.13 (0.195)	16.9	12.4	0.11	13.1	21.3
	Yellow Brown Earth	2	5.0	543	5.5	0.05	22.3	10.7	0.11	21.2	12.7
	Christchurch urban	Gley	6	6.0	706.1	12.5	0.21	20.3	25.0	0.13	17.5
Organic		2	7.8	352	15.1	0.12	12.7	14.8	0.20	13.1	47.3
Recent		8	8.1	634.3	16.3	0.2	20.1	19.5	0.1	18.0	128.8
Saline Gley Recent		2	22.8	403	8.6	0.07	25.4	11.9	0.09	15.9	36.3
Yellow Brown Sand		4	5.4	383.1	5.9	0.09	16.6	10.2	0.09	12.3	25.3
Timaru urban	YGE	5	5.00	613.00	3.46(12.06)	0.12	12.95	14.40	0.13	9.53(23.33)	63.40
											132.05

## 8.1 Quality control and quality assurance

To reduce the risk of field errors during sampling the following quality control measures were undertaken:

- A checklist was used for the sampling methodology to ensure all tasks were completed and in the correct sequence;
- Photographs were taken of sample labels prior to taking site photographs. If a labelling error did occur the photographs could be referenced against the site photos and the error corrected;
- Following the collection of samples from each location, all sampling equipment was cleaned by brushing and wiping off all soil, and triple rinsed with deionised water (and Decon 90 for Christchurch Urban soils) to remove any remaining trace of soil, and
- Upon receipt of the job cover sheet from the laboratory, all samples were cross checked against the chain of custody to ensure samples were received and recorded correctly.

To ensure that the sample results were an actual representation of the true soil concentration and that they were repeatable, rinsate blanks and field duplicates were collected.

Rinsate blanks were collected by rinsing sampling equipment at the end each day with filtered water, collecting the water and analysing it for the 10 trace elements. This was done to determine if residual contaminants were present on the sampling equipment which may have caused cross-contamination of samples.

Field duplicates involved collecting two samples at the same location, and sending both to the laboratory for analysis. One rinsate blank was analysed during this project, and 1 duplicate sample was analysed.

The results for the field duplicate are in Table 3. This includes both duplicates and a calculated composite value (AS\_RE\_S2 calc) from the three non-outlying sub samples of AS RE S2.

**Table 3 Comparison of field duplicates and relative percent differences (all results in mg/kg).**

	AS_RE 2	AS_RE 2b	AS_RE 2 calc	RPD <sup>1</sup>
Boron	6	5	5	0
Mn	531	495	538	-8%
As	4.4	3.3	2.97	11%
Cd	0.10	0.07	0.06	15%
Cr	15.1	15.3	14.6	5%
Cu	439	10	11	-11%
Hg	0.07	0.03	0.04	-20%
Ni	9.6	9.4	9.2	3%
Pb	1090	17.5	22.5	-25%
Zn	112	62.9	60.6	4%

<sup>1</sup> The RPD is between AS\_RE2b and AS\_RE 2 calc

A clear difference exists between the two original duplicates. This was due to one of the sub samples being highly elevated for copper and lead. All the relative percentage differences (RPD) between the calculated composite (AS\_RE 2 calc) and the field duplicate results were below 30% and all were within the range of expected natural and analytical variation. This indicates that aside from the effect of the elevated sub sample, the sampling method and the laboratory techniques were valid and repeatable and there were no QA/QC issues with the sampling.

The data from the rinsate blank are shown in Table 4.

**Table 4 Rinsate blank results (all results in g/m3)**

	Rinsate blank 23/01/07
Boron	0.02
Mn	0.0242
As	<0.001
Cd	<0.00005
Cr	0.0031
Cu	0.0033
Hg	<0.00008
Ni	0.0013
Pb	0.0014
Zn	0.044

Although traces of most metals were detected in the rinsate blank, the concentrations are low in relation to the concentrations detected in the soil analysis. Therefore any residual contaminants left on the sampling equipment after cleaning would have had no effect on measured soil concentrations.

## 9 Discussion

The additional data collected in this stage of the project generally showed higher trace element concentrations than the original data set. The background levels for all analytes of the recent soil group in the Christchurch urban area were increased. All other soil groups showed a mixture of no change and an elevation of the Level 1 background levels.

Overall the Level 2 background levels were increased with the addition of the new data set. The Level 2 background concentrations did lower for some elements in some soil types. This was due to the additional data reducing the variability and decreasing the interquartile range and the buffer size.

Outliers from the existing data set were mostly retained in the updated data set. The additional data in the Recent soil group enabled the reduction of two of the outliers. One additional outlier was added to the Christchurch Urban data.

The Timaru background levels (1 and 2) were within ranges of other values observed in Canterbury and Christchurch. Two outliers currently exist in the data set. However with further data providing a better indication of the natural variation, it is expected that these outliers could be removed.

## 10 Recommendations

While the additional data often increased the Level 1 background concentration, the reductions in some of the Level 2 background levels and removal of some outliers indicates the sampling is beginning to capture the natural variation present in trace elements concentrations.

Significant variation and outliers are still present in the data sets, primarily due to the large sample area and relatively small sample size. Further sampling would increase the confidence of the background predictions by capturing more of this variation. As the Christchurch urban area levels are likely to be used the most often, further sampling of this area should be a priority.

With additional samples being added to the data set, further statistical analysis could be undertaken to assess if the larger data set approximates a parametric distribution. Being able to fit the data to a distribution would be advantageous and allow a more confident prediction of the background levels.

## 11 Conclusions

The additional sample data provided a valuable increase in the size of the trace elements data set. Generally the additional data increased the background concentrations, although decreases for some Level 2 concentrations occurred. Outliers still exist in the data set, and additional sampling is required to further assess these outliers. Samples taken within Timaru have enabled background trace element concentrations to be established for the Timaru urban soils.

## 12 References

- ARC (2001) Background concentrations of Inorganic Elements in Soils from the Auckland Region. TP No. 153.
- Tonkin and Taylor Ltd (2006) Background concentrations of selected trace elements in Canterbury soils.
- Tonkin and Taylor Ltd (2007) Background concentration of PAH compounds in Christchurch urban soils.
- URS Ltd. (2005) Sampling Methodology for determining Background Soil Quality in Canterbury. Report Prepared for Environment Canterbury.

### 13 Applicability

This report has been prepared for the benefit of Environment Canterbury with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

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