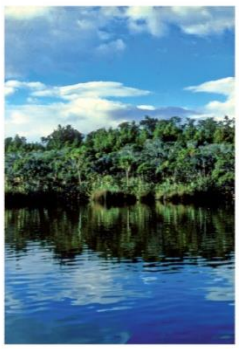

Background concentrations of trace elements and options for managing soil quality in the Tasman and Nelson Districts

Envirolink Advice Grant: 1555-TSDC110

Landcare Research
Manaaki Whenua

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What impressed you most about this project?

What improvements do you suggest for future projects?

Additional comments?

Contents

Summary

Project and Client

- This report provides an assessment of background concentrations of selected trace elements in soil, based on existing data, for the Tasman and Nelson region and recommendations for concentrations that can protect ecological receptors on-site (or within cleanfill sites). This project was undertaken for Tasman District with funding from Envirolink (Medium Advice Grant TSDC1555).

Objectives

- To determine background concentrations of inorganic soil contaminants using existing data for the Tasman/Nelson region.
- To provide recommendations for concentrations that can be considered to protect ecological receptors on-site (or within cleanfill sites), to ensure that land does not become contaminated from a Resource Management Act perspective.

Methods

- Statistical analyses of trace element concentration data provided by Tasman Council were undertaken using R version 3.0.2, to determine the 95th and 99th percentile, while a bootstrapping technique was used to determine the upper confidence limit of the 95th percentile. Additional analyses were conducted using geological data extracted from spatial databases (S-Map, LRI and Q-Map) for the sites for which trace element data was available.
- The existing approaches to determining soil quality guidelines were reviewed, including the derivation of soil guideline values to protect ecological receptors (Eco-SGVs) and cleanfill criteria, and used to provide recommendations to assist in managing soil quality.

Results

- Soil quality monitoring data and data from contaminated land investigations provided trace element concentration data for 52 sites of varying land use across the Tasman/Nelson Region to determine background soil concentrations of trace elements.
- Various terms are used to describe background soil concentrations of naturally occurring trace elements. Baseline concentrations most accurately describe the concentrations determined from soil monitoring undertaken in the Tasman/Nelson region to date. Baseline concentrations may be analogous to natural background for chemical substances at sites not influenced by diffuse or other anthropogenic sources.
- Two sites appeared to be influenced by anthropogenic contamination and were excluded from subsequent data analysis. Elevated concentrations of Cr and Ni were typically found in Recent soils. Extraction of additional data from the spatial databases did not provide any identifiable features delineating sites with elevated concentrations.
- Preliminary estimates of the upper limit for background concentrations were based on the 99th percentile and are shown below alongside recommended interim cleanfill criteria.

- Interim cleanfill criteria in Tasman/Nelson region have been developed to ensure the land does not become contaminated for the most sensitive receptor (ecological receptors or people). These criteria include a ‘‘buffer’’ to ensure that exceeding a cleanfill threshold by a minor margin does not inadvertently allow for deposition of contaminated soil. As such, the criteria are more conservative (i.e. lower) than criteria that might be used for protection of ecological receptors or human health (e.g. Soil Contaminant Standards used in the National Environmental Standard for assessing and managing contaminants in soil for the protection of human health).

Table S1 Recommended interim cleanfill criteria

Element	N	99th percentile	Cleanfill criteria based on protection of ecological receptors	Cleanfill criteria based on protection of human health	Recommended cleanfill criteria
As[1]	47	11	20.6	12.8	12
Cd	29	0.90	1.7	0.75	0.75
Cr-hi[2]	8	183	*	*	-
Cr-lo[3]	21	93.5	140	-	140
Cu	43	41.5	85.4	-	85
Pb	48	33	86.4	93.2	86
Ni-hi[2]	8	274.4	*	*	-
Ni-lo[3]	21	53.4	88	91.5	88
Zn	29	141.5	308	-	300

[1]Arsenic concentrations excluding the elevated point (18 mg/kg); [2]Subgroup of sites with seemingly naturally elevated Cr and Ni concentrations; [3]Subgroup of sites with seemingly normal concentrations of Cr and Ni; *Given the small number of samples in these groups, no cleanfill criteria are given.

- Criteria based on protection of ecological receptors is based on previously derived Eco-SGVs, although a current Envirolink Tools project is looking at parameters influencing background soil concentrations nationally and developing Eco-SGVs based on an agreed methodology.

Recommendations

- Additional sampling is required to develop more robust estimates of background concentrations of trace elements in the Tasman/Nelson region. Specifically, additional sampling is required on agricultural land use on Ultic soils, and exotic and indigenous forest, and scrub and shrubland sites that are primarily located on Brown, Ultic, Podzol and Melanic soils. Sampling at locations across the region where anthropogenic input of trace elements is not expected would also provide additional data to support the development of more robust estimates of background soil concentrations.
- Further sampling in the vicinity of the locations with identified elevated Cr and Ni should be undertaken to better delineate the region of elevated concentrations and/or further geological information sought to identify the extent of the area likely to contain elevated Cr and Ni.
- Criteria should be reviewed after completion of the Envirolink Tools project.

1 Introduction

The Tasman–Nelson area is nationally a major horticultural producer, with much of the area previously subject to persistent orchard sprays now being developed for lifestyle or residential uses. The *National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health* requires that any soil removed during development of horticultural/orchard sites must be ‘‘disposed of at a facility authorised to receive soil of that kind’’. Currently, the only options for managing soil from these sites appear to be for the soil to remain on-site or to be disposed to one of the two municipal landfills in the Tasman/Nelson area. Diverting all this material to municipal landfill is both very expensive for the user (c. $200 per cubic metre) and wasteful of landfill capacity, particularly where the potential impacts on human health or the wider environment is low. Further, developers are experiencing serious time delays and significant costs as the requirements for management of soils with low level contamination remain undefined.

Background concentrations and ecological protection limits for soil contaminants can be used to guide decisions regarding what soil contamination levels are safe to retain on-site (or move to a clean fill area) as opposed to what soil requires specialised management and/or disposal.

This report provides an overview of approaches to determining background and ecological acceptance criteria for management of inorganic contaminants in soils in the context of current contaminated land management practices in New Zealand. The project analysed existing local soil data to determine background concentrations of inorganic soil contaminants and recommends what concentrations of inorganic contaminants can be considered to be ‘background’ within specified geologic or soil units, and what concentrations can be considered to protect ecological receptors on-site (or within cleanfill sites), in order to ensure that land does not become contaminated from a Resource Management Act perspective.

2 Background

2.1 Background concentrations

Increasing recognition is being given to the importance of knowing background soil concentrations of various trace elements to assist with managing soil quality (noting that recent recommendations for the development of soil guideline values for the protection of ecological receptors (Eco-SGVs) in New Zealand (MPI 2012) allows for the inclusion of background concentrations in the development of Eco-SGVs for selected substances); management of contaminated land (e.g. the recently implemented National Environmental Standards for contaminants in soil do not apply if it can be demonstrated that any soil contaminants are at, or below background concentrations); waste disposal (e.g. cleanfill criteria) and for assessing soil quality.

There are three different definitions for background concentrations:

Natural background – The concentrations of naturally occurring elements derived/originating from natural processes in the environment as close as possible to natural conditions, exclusive of specific anthropogenic activities or sources. (May also be referred to as the geochemical background.)

Ambient background – The concentrations of chemical substances in the environment that are representative of the area surrounding the site not attributable to a single identifiable source. This can include contaminants from historical activities and widespread diffuse impacts, e.g. fallout from motor vehicles.

Baseline – The soil concentrations of chemical substances in a specified location at a given point in time. Baseline concentrations are analogous to natural background concentrations where the specified locality is not influenced by diffuse or other anthropogenic sources, or to ambient concentrations when the specified locality is influenced by diffuse anthropogenic sources. In contrast to ambient and natural background concentrations, baseline concentrations also include concentrations in locations known to be influenced by land use (e.g. agricultural land use).

Baseline concentrations most accurately describe the concentrations determined from soil monitoring undertaken in the Tasman District to date. As noted above, baseline concentrations may be analogous to natural background for chemical substances at sites not influenced by diffuse or other anthropogenic sources. For the sites under consideration, this is likely to apply to chromium (Cr) and nickel (Ni), arsenic (As), and lead (Pb) (although there is potential for historical use of lead arsenate pesticide). There may be some use of products containing copper (Cu, copper-based fungicides), cadmium (Cd, phosphatic fertilisers), and zinc (Zn, facial eczema treatment) on some land uses that may elevate the concentrations of these naturally occurring trace elements.

3 Objectives

This project will:

- provide an overview of approaches to determining background and ecological acceptance criteria for management of inorganic contaminants in soils in the context of current contaminated land management practices in New Zealand.
- determine background concentrations of inorganic soil contaminants using existing data
- recommend concentrations that can protect ecological receptors on-site (or within cleanfill sites), in order to ensure that land does not become contaminated from an RMA perspective.

4 Methods

Existing soil quality monitoring data was provided by Tasman District Council and providing concentration data for As, Cd, Cr, Cu, Pb, Ni, and Zn for 30 locations. To provide a larger data set, additional data from contaminated land investigations were also provided by consultants, for sites considered to have not been influenced by anthropogenic contamination.

This yielded an additional 26 sites, although often only As and Pb were measured in these samples. For the additional site data, where a number of samples were collected from the same location, the mean concentration was calculated and a single value used in subsequent data analysis.

Statistical analyses were undertaken using R version 3.0.2, to determine the 95th and 99th percentiles, with bootstrapping undertaken to determine the upper confidence limit of the 95th percentile. Geographical information systems were used to map the location of sampling sites in relation to soil order, while data from Landcover database 4 (LCDB4) were used to map the location of sample sites in relation to land cover.

To examine the influence of geological parameters on soil concentrations, information was extracted and analysed from three existing spatial databases :

- The Land Resource Information System (LRIS, http://lris.scinfo.org.nz/) allows the public to access environmental data held by Landcare Research. Data layers available include soil fundamental data layers (FDLs), vegetation data layers, and land-cover. The FSL NZ Soil Classification is a spatial database that describes land on the basis of five characteristics, including rock type. Data on rock type from each of the sampling locations were extracted.
- S-Map is a spatial database within LRIS for New Zealand soils that has been designed to provide quantitative soil information for modellers and to provide the best available soil data for use by land managers and policy analysts (Lilburne et al. 2012). S-Map includes linkages to the National Soils Database. Data on rock class of fines (<2 mm) from each of the sampling locations were extracted.
- Q-Map, a national spatial database containing geological information, was developed by GNS over the period 1993–2012. It provides geological maps at 1:250 000 scale across New Zealand. Data on 'rock group' for each of the sampling locations were extracted.

5 Results and discussion

5.1 Background soil concentrations

An initial assessment of the data to determine whether there were any outlying points that should be excluded from subsequent analyses indicated some elevated concentrations of As, Pb, Cr and Ni. Scatter-plots of As and Pb (indicating historic lead arsenate use), and Cr and Ni (Cr and Ni may be elevated in ultramafic rocks; elevation in one or the other may indicate anthropogenic contamination) were used to indicate outlying points (Figure 1). From this, two sites with elevated concentrations indicative of anthropogenic contamination were identified and removed from the dataset for subsequent analysis. This included one site (indicated as being used for wastewater disposal) on which all elements except Cd were elevated (Figure 1a & b) and another site (an orchard site) that showed elevated As (21 mg/kg), Cu (58 mg/kg) and Pb (119 mg/kg) (Figure 1 a), which may suggest the historic use of lead arsenate and copper sprays as pesticides or fungicides. A further site (part of the contaminated land investigation data set) located in an urban area was elevated in Cu (72

mg/kg), a common contaminant in urban environments; this copper concentration was excluded from determination of background Cu concentrations.

Some other sites showed elevated concentrations but were retained in the data set as the elevated concentrations could not definitively be attributed to anthropogenic contamination. For example, one site had elevated As (18 mg/kg) in the absence of elevated Pb, and elevated Cr (95 mg/kg) in the absence of elevated Ni (Figure 1c, d). Another site was elevated in Pb, but not As (Figure 1c). Further assessment should be undertaken to confirm the elevated lead concentration is not due to contamination by lead-based paint.

As is shown in Figures 1b and d, there is a strong correlation between Cr and Ni concentrations, with two apparent clusters of sites (Figure 1 d). Sites with elevated Cr and Ni are clustered around the Waimea floodplain (Figure 2), with the exception of the western-most site, which had elevated Cr (and As) but not Ni. (Note: Figure 1a shows the concentration for all sites. The southern-most site had low concentrations for all elements and is not shown in subsequent plots.) Sources of anthropogenic contamination of Ni are mainly limited to electroplating industries, although electroplating activities are likely to result in elevated concentrations of a range of metals in addition to Ni. Thus, the clustering of sites with elevated Cr and Ni suggests a potential geological influence on concentrations. At a more detailed scale, some locations with elevated concentrations are adjacent to locations with low concentrations (Figure 3). This may indicate of the presence of small outcrops of ultramafic rocks in these headwaters; a greater influence of ultramafic rocks would be expected in the western valleys draining the Moutere Gravels. Further sampling is required to establish spatial extent and variability of elevated concentrations of Cr and Ni within the Waimea floodplain region. In contrast, the concentrations of other trace elements show a more even distribution across the sampled region (Figures 4 and 5).

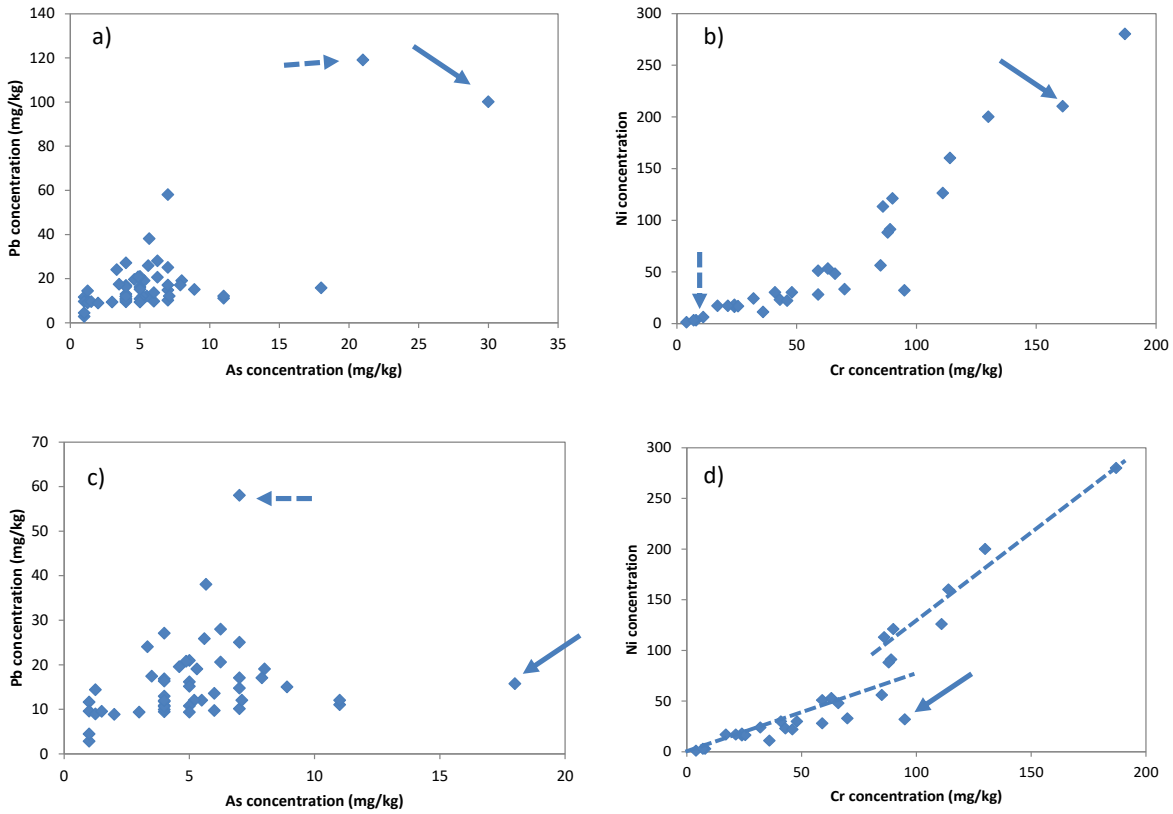


Figure 1 Scatterplots showing relationship between As and Pb, and Cr and Ni concentrations, in the full dataset (a, b) and the reduced dataset (c, d). The solid arrow in a) and b) shows the concentrations at the site that received waste-water; and the dashed arrow in a) shows the As and Pb concentrations present at the orchard site that were excluded from subsequent data analysis. The solid arrow in c) and d) shows that site with elevated As, bu not Pb, while dashed arrow shows the site with elevated Pb but not As (Cr and Ni were not measured at this site.

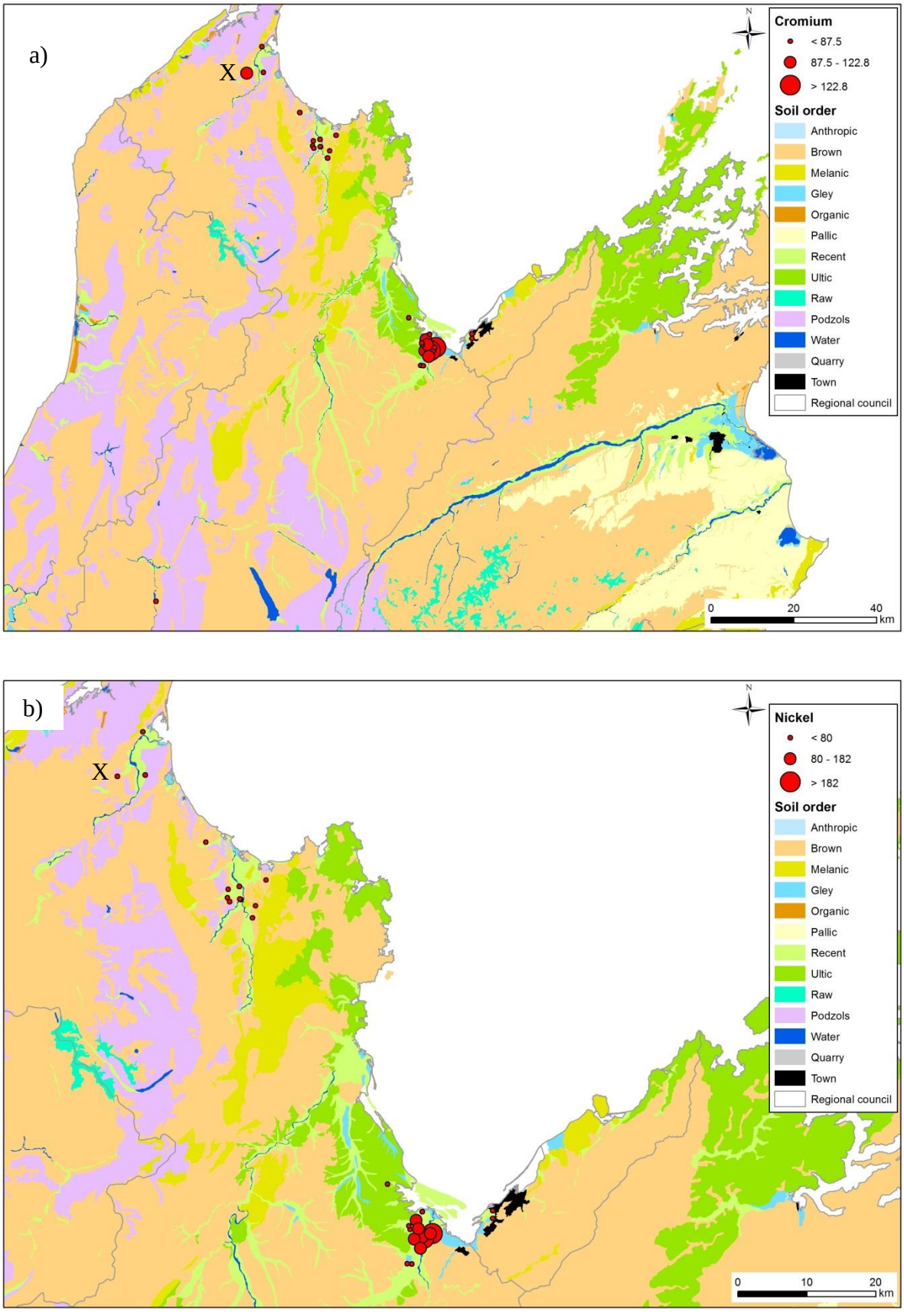


Figure 2 Concentrations of a) Cr and b) Ni, and the distribution of soil order, across Tasman/Nelson region. X indicate site with elevated Cr but low Ni.

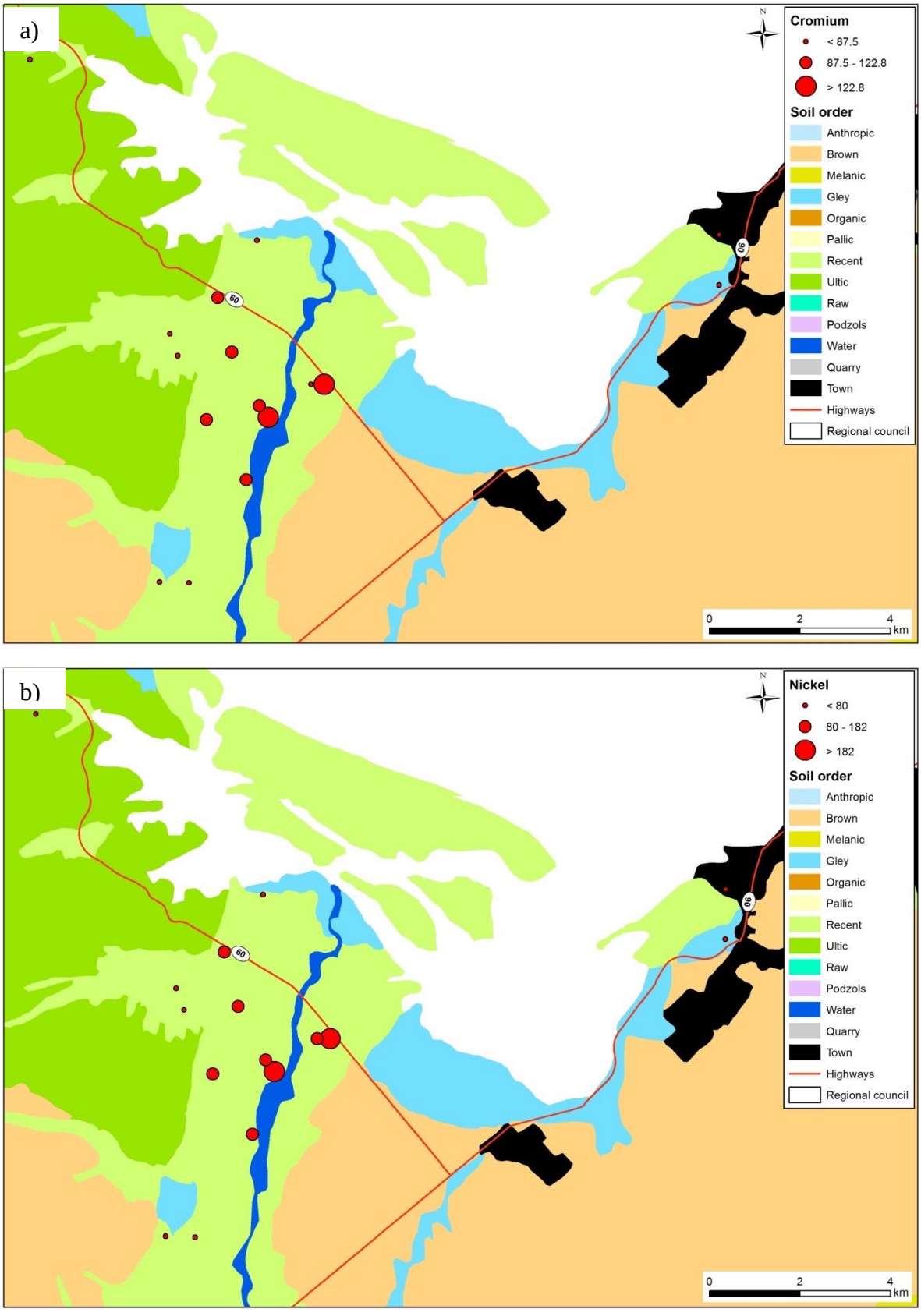


Figure 3 Higher resolution mapping of centrally clustered sites with elevated a) Cr and b) Ni concentrations (mg/kg) from Figure2.

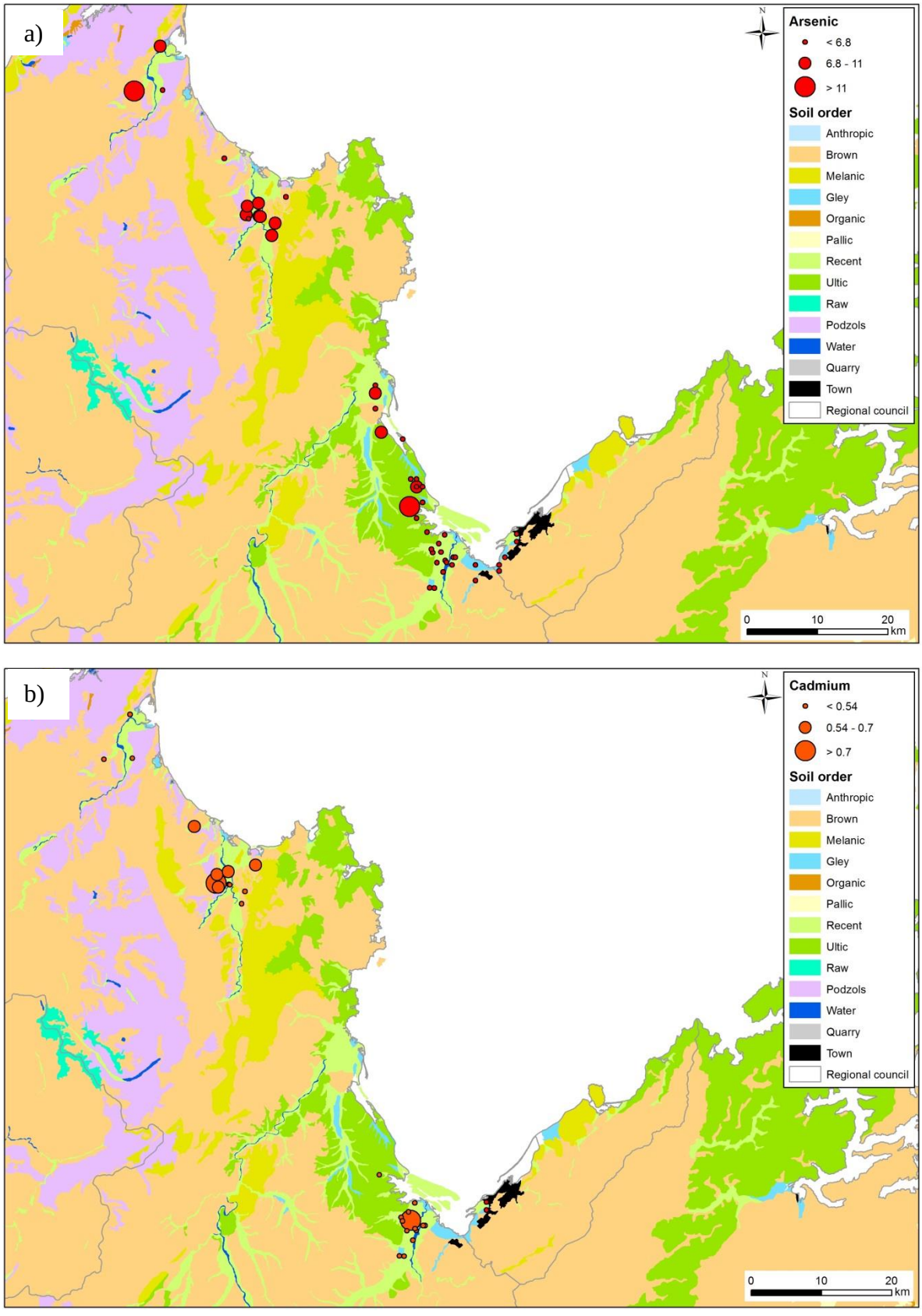
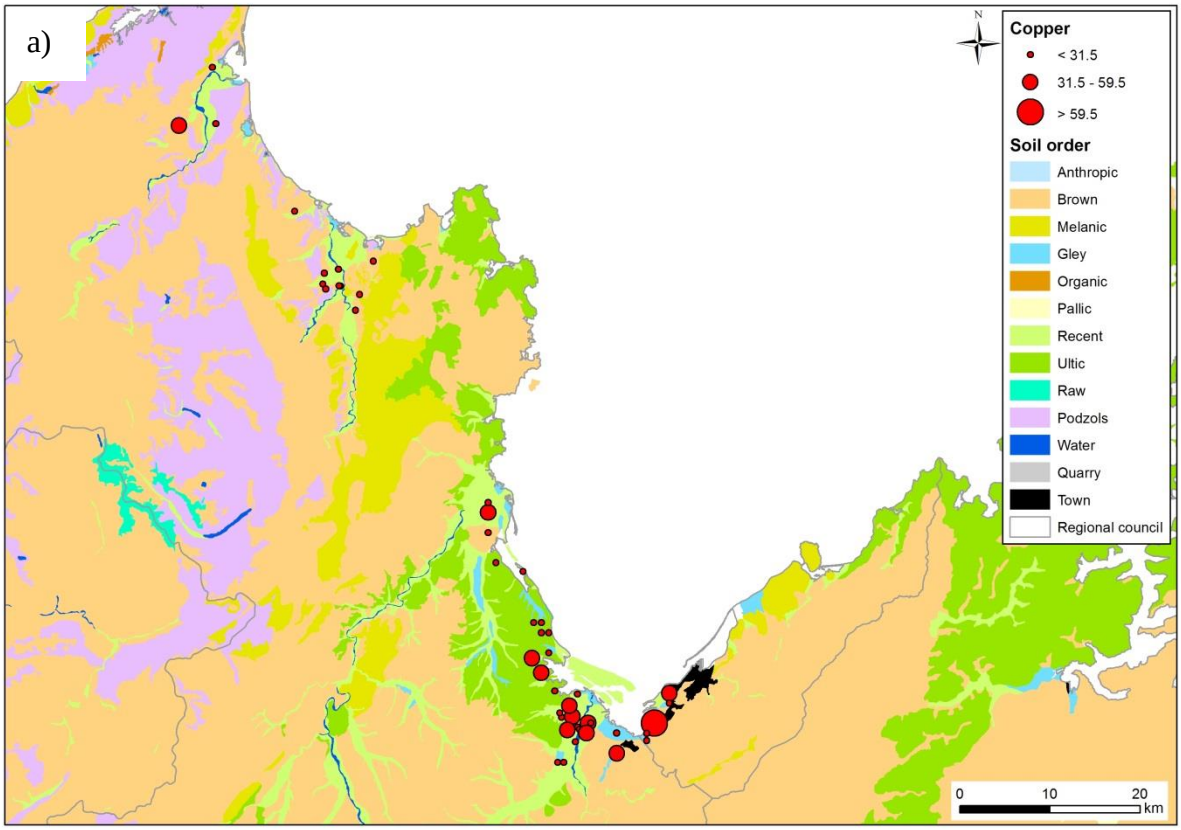
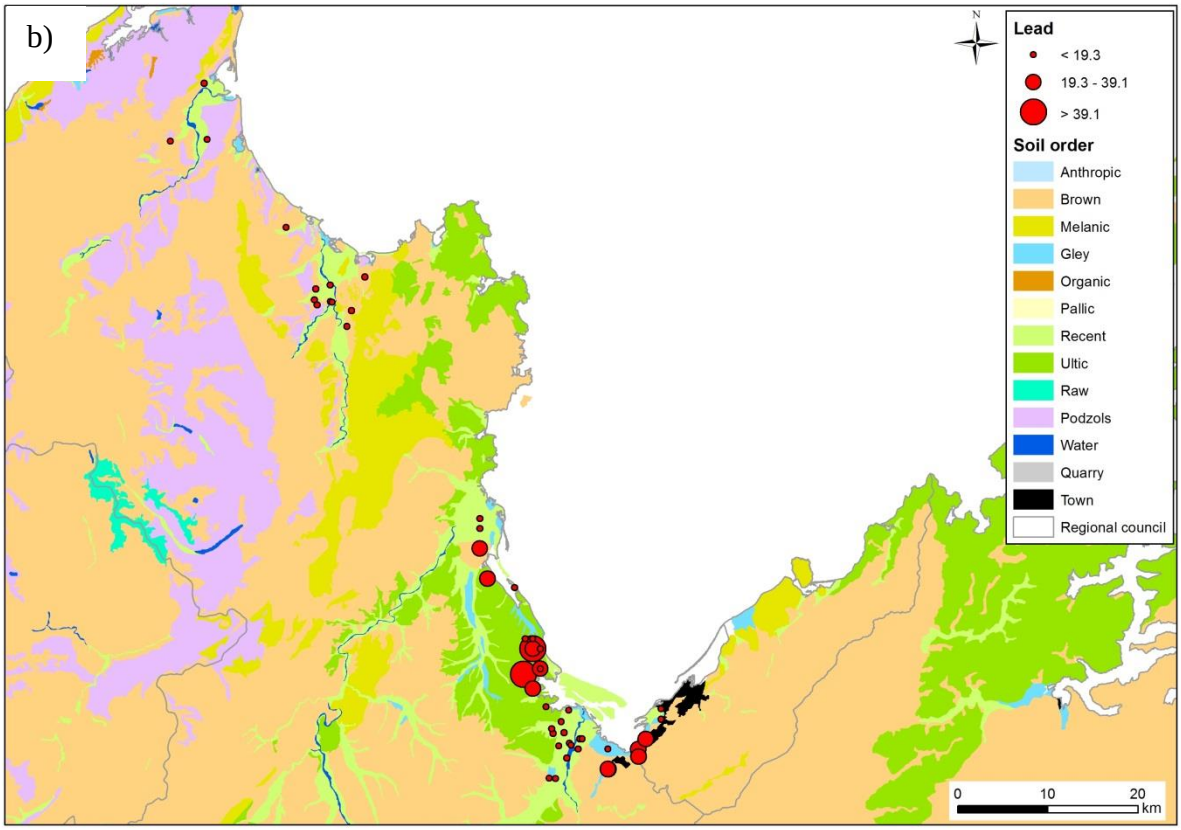


Figure 4 Distribution of a) As, b) Cd concentrations at sites sampled across the Tasman/Nelson region.


a)
N
Copper
< 31.5
31.5 - 59.5
> 59.5
Soil order
Anthropic
Brown
Melanic
Gley
Organic
Pallic
Recent
Ultic
Raw
Podzols
Water
Quarry
Town
Regional council
0
10
20
km


b)
N
Lead
< 19.3
19.3 - 39.1
> 39.1
Soil order
Anthropic
Brown
Melanic
Gley
Organic
Pallic
Recent
Ultic
Raw
Podzols
Water
Quarry
Town
Regional council
0
10
20
km

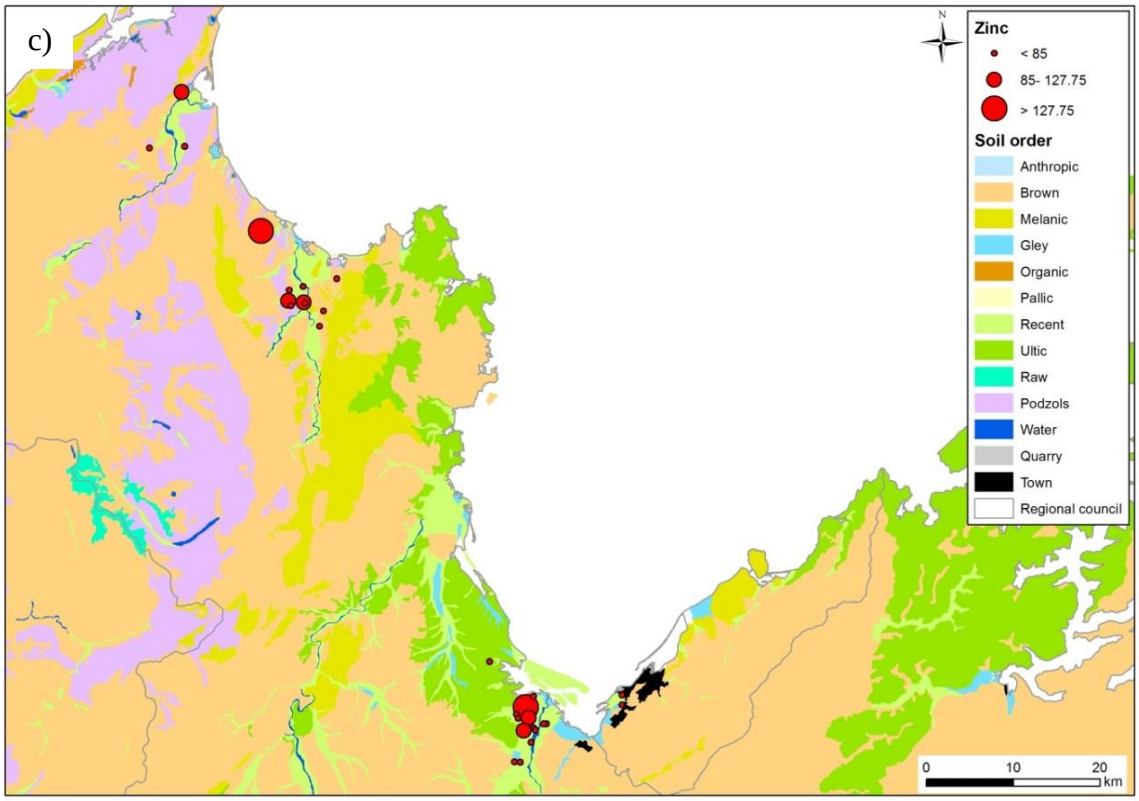


Figure 5 Distribution of a) Cu, b) Pb, and c) Zn concentrations at sites sampled across the Tasman/Nelson region.

A summary of the concentrations of As, Cr, Cu, Pb, Ni and Zn for all sites retained for subsequent analyses are shown in Figure 6. The detailed data for all individual sites is provided in Appendix 1. Lead and zinc had a relatively narrow concentration range, suggesting there is minimal influence of geology on the concentration of these elements across the sampled locations. However, further investigation of the sites of elevated Pb would be useful to determine if these are influenced by anthropogenic contamination, e.g. lead-based paints, or whether they are reflective of the natural variability of the soils. A wider distribution in the range of Cu, Cr and Ni concentrations was observed, likely indicating greater geological variability.

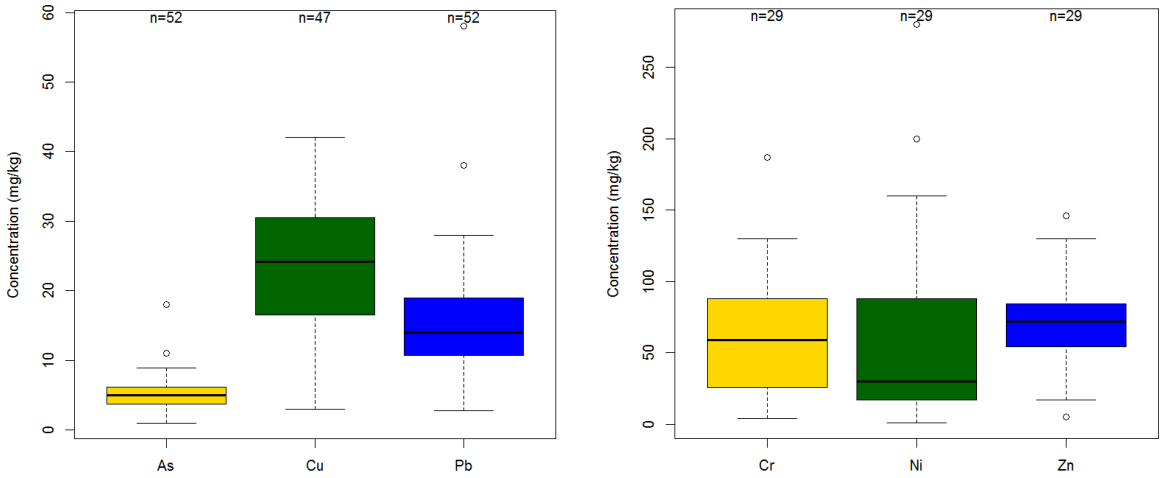


Figure 6 Boxplot showing spread of concentration (mg/kg) for individual trace elements, excluding Cd.

Different limits have been used to define the upper limits of background concentrations and Cavanagh (2013a) has argued that consensus was needed for the appropriate upper limit(s) (e.g. 99th percentile, 95th UCL, median) to be used for different land management purposes. The 95th percentile of concentrations from locations under different land uses has been used in the development of some cleanfill criteria in New Zealand (Cavanagh 2013b). In contrast, the 99th percentile concentration of arsenic in NZ soils thought not to have been affected by anthropogenic activities was used as the soil contaminant standard (SCS) for the rural-residential land use scenario in the National Environmental Standard, as the derived value for this scenario was below this concentration. Similarly, the 99th percentile concentration of cadmium in NZ soils thought not to have been affected by anthropogenic activities is used to define the first tier of the Tiered Fertiliser Management System for Cadmium (MAF 2011). Internationally, the upper confidence limit of the 95th percentile is typically used as the upper limit for background soil concentrations (see Cavanagh 2013a), although some authors indicate there is little difference between that and the 99th percentile value (Diamond et al. 2009).

A summary of the background soil concentrations for individual trace elements, along with calculated 95th percentile, the upper confidence limit of the 95th percentile, and the 99th percentile concentrations are shown in Table 1. As can be seen, the upper confidence limit of the 95th percentile and the 99th percentile concentrations are very similar as observed by Diamond et al. (2009).

Table 1 Summary of concentrations (mg/kg) of individual trace elements, and various estimates of upper limits for nominal background concentrations. Estimates are provided for the two identified sub-groups of Cr and Ni concentrations, and including and excluding the site with the highest As concentration.

Element	No. sites	Max	Min	Median	95th percentile	95UCL	99th percentile
As	48	18	<2	5	10.3	15.6	14.7
As2[1]	47	11	<2	5	8.6	11	11
Cd	29	0.96	<0.1	0.24	0.70	0.96	0.90
Cr-hi[2]	8	187	88	100.5	167	187	183
Cr-lo[3]	21	95	4	41	85	95	93.5
Cu	43	42	3	24.2	40.4	41.7	41.5
Pb	48	58	2.8	13.6	26.4	32.5	33
Ni-hi[2]	8	280	88	123.5	252	280	274.4
Ni-lo[3]	21	56	<2	23	53	56	53.4
Zn	29	146	5	72	128	146	141.5

[1]Excluding the most elevated As (18 mg/kg) or Cu (58 mg/kg) concentrations

[2]Sub-group of sites with seemingly naturally elevated Cr and Ni concentrations

[2]Sub-group of sites with seemingly normal concentrations of Cr and Ni

The choice of appropriate upper limit may depend on the spread of concentrations (and therefore the difference between different upper limits) and the degree of precaution desired in the context of the derived value, e.g. for cleanfill criteria. For the current work, 99th percentile concentrations were used as the upper limits as compared to the 95th upper confidence level of the 95th percentile concentrations (95UCL), which was used in Cavanagh (2014b), as the 95UCL often equalled the maximum measured concentration.

However, the choice of upper limit for each trace element may be less significant than identifying appropriate 'groupings' of soils with similar features, and determining an upper limit for those groupings (e.g. for Cr and Ni in table 1). Further analyses of existing data to identify key factors influencing trace elements using spatial tools such as S-Map is discussed in section 5.2.

5.2 Representativeness of estimates of background concentrations

The land use at the sampling sites and the locations of cleanfills in the region is mapped with the distribution of different land-cover classes (Figure 7) and soil orders (Figure 8) across Tasman-Nelson Region. Existing sample information is available from agricultural sites, and land (often ex-agricultural) being subdivided or developed across the region. Agricultural land use is located mainly on Brown, Recent and Ultic soils and the most obvious gaps in sampling locations are exotic forest, indigenous forest and scrub and shrubland sites, which are primarily located on Brown, Podzol and Melanic soils, and agricultural land on Ultic soils. The distribution of sampling locations also reflects the distribution of cleanfills (Figures 7 and 8), and thus provide relevant information on soil concentrations for the cleanfill sites.

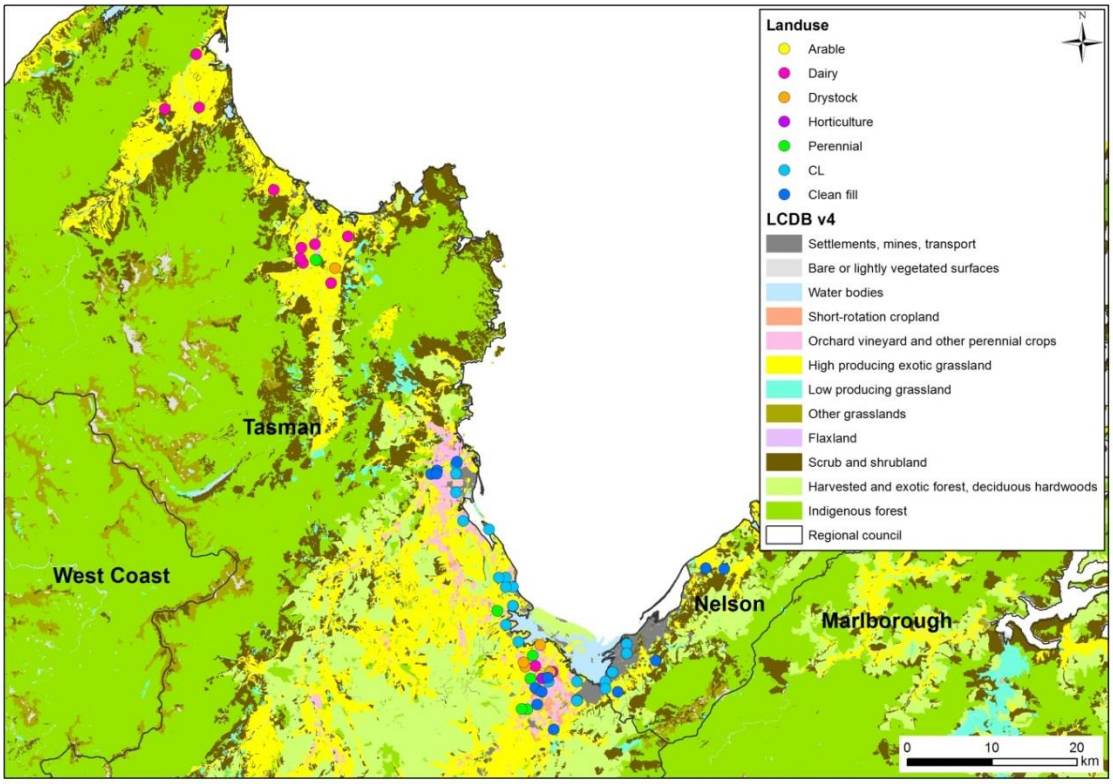


Figure 7 Location and land use at each sampling site (CL indicates sites obtained from contaminated land investigations) and distribution of different land-cover classes (LCDB v4) across the Tasman/Nelson region. The location of cleanfills (dark blue) are also shown.

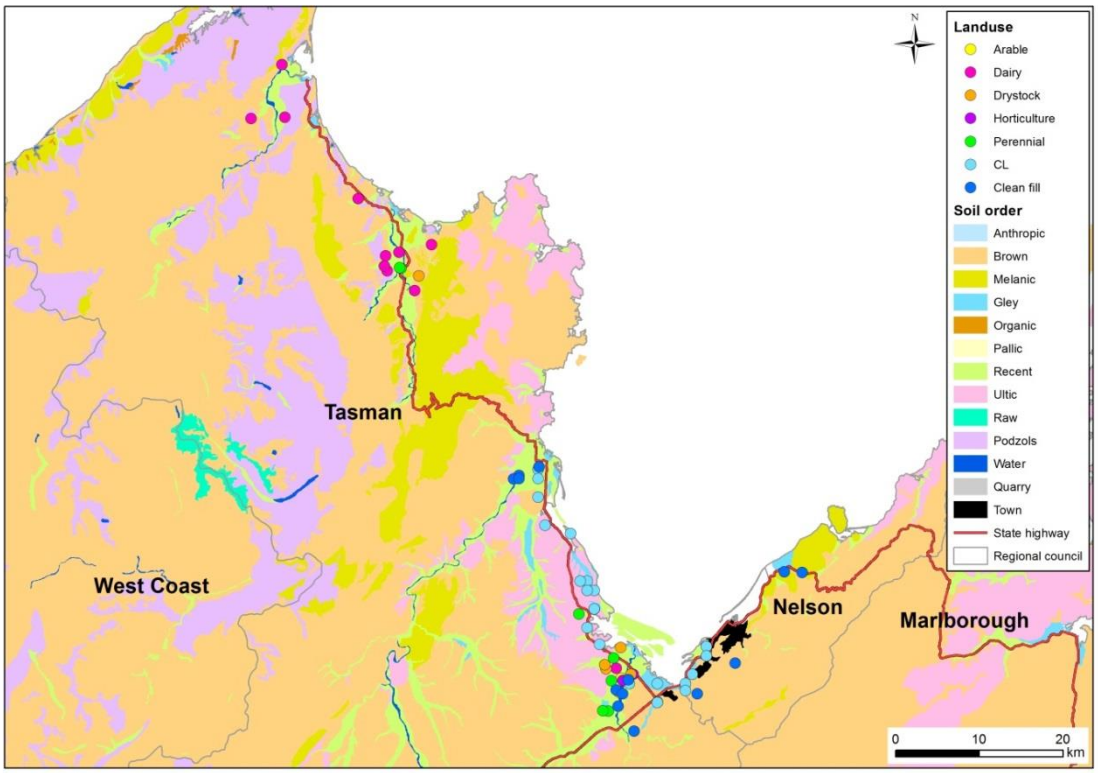


Figure 8 Location and land use at sampling sites (CL indicates sites obtained from contaminated land investigations) and sites and distribution of soil order across Tasman/Nelson region. The location of cleanfills (dark blue) are also shown.

The key drivers of variation of naturally occurring trace element concentrations in NZ soils have not been identified, although it is generally considered that the geological origin of the parent material of the soil will influence concentrations, for example basic rocks with higher concentrations of mafic minerals often have elevated Cr and Ni. Spatial databases, such as S-Map, LRIS and Q-Map (see Cavanagh 2013a for more detailed description of these databases), were used to extract information related to the soil parent materials at the sampling locations (Table 2). There are constraints in extracting site-specific data from these databases due to the mapping scales used (i.e. the information extracted for a given site will be the predominant 'value' for the relevant mapping unit, which may or may not be strictly accurate for that site). However, such information may be useful in identifying general patterns. In this study, while concentrations of individual trace elements vary across the sites, there is limited variation in the geological parameters, with rock types predominantly being alluvium (LRIS) or gravel (QMap) or hard sedimentary sandstone (S-map, noting that only approximately 20% of sites were included in S-Map database). While a broader range of soil orders were sampled, Brown and Recent soils were the predominant orders sampled. Further sampling across the region, including sites of differing geological origin, will assist in determining whether the initial estimates of background concentrations (Table 1) are applicable across the wider region. Information extracted from the databases did not identify any parameters that might explain elevated Cr and Ni concentrations. A Ministry of Business, Innovation and Employment Envirolink Tools project ('Background concentrations and soil guideline values for the protection of ecological receptors') is looking at parameters influencing background soil concentrations nationally and draws upon the Tasman/Nelson region data (Cavanagh 2014a); this nationwide analysis will be available by September 2015 and may provide further insight into background concentrations across the Tasman/Nelson region.

Table 2 Soil order and rock classifications extracted from S-Map, LRIS or Q-Map for the Tasman District Council soil monitoring locations. Number of samples is given in brackets for each classification.

Soil order (LRIS)	'Rock-type-of-fines' (S-Map)	Rock (LRIS[1])	Main rock (Q-map)
Brown (15)	Hard sedimentary sandstone (9)	Al (40)	Gravel (51)
Gley (5)	Granite (1)	Cw (13)	Sand (2),
Podzol (1)			
Recent (19)			
Ultic (13)			

[1] Al = alluvium; Cw = weakly consolidated conglomerate

5.3 Management of soil quality

Protecting ecological receptors (Eco-SGVs)

Soil guideline values developed to protect soil biota (Eco-SGVs) provide a useful means to readily assess potential environmental impact. Comprehensive review of international approaches to developing soil guideline values for the protection of ecological receptors has

been provided in Cavanagh and O'Halloran (2006) and MPI (2012). Essentially, Eco-SGVs are developed by:

- compiling toxicity data for soil invertebrates, plants and microbial processes
- using statistical extrapolation, where sufficient data are available, or assessment factors to derive criteria.

However, there are a number of choices that can be made in developing soil guideline values, including the toxicity data used, which may be either the 'no observed effect concentration' (NOEC); the concentration at which 10% of the test population were affected (EC10); or the lowest observed effect concentration, and the level of protection provided, e.g. 95% or 50% of species. Further, an 'added-risk approach' has been increasingly used to develop Eco-SGVs for naturally occurring elements. This approach considers that species are fully adapted to the natural background concentration, and therefore only the anthropogenic added fraction should be regulated or controlled. Thus, the concentrations based on statistical analysis of toxicity data are *added* to the determined background concentrations. Agreement is required on the appropriate methodology used to develop Eco-SGVs to ensure national consistency and applicability of Eco-SGVs.

In New Zealand, some soil guideline values that provide protection for ecological receptors already exist, e.g. within the Timber Treatment Guidelines (MfE 2011) or Biosolids Guidelines (NZWWA 2003), but these are for a limited number of contaminants and are based on inconsistent methodologies. 'Minimal risk' and 'serious risk' guideline values for the protection of ecological receptors developed by Cavanagh and O'Halloran (2006) and Cavanagh (2006) for Auckland Regional Council provide Eco-SGVs for a wide range of contaminants using a consistent methodology, although they do not have national recognition. The absence of national Eco-SGVs has resulted in inconsistency and a lack of clarity around protection of ecological receptors in soil, and a lack of focus on ensuring this protection in territorial and regional/unitary council functions. Recognising this, a Ministry of Business, Innovation and Employment Envirolink Tools project ('Background concentrations and soil guideline values for the protection of ecological receptors') commenced in July 2014, to develop a nationally agreed methodology for deriving Eco-SGVs, and to develop Eco-SGVs for priority contaminants (Cavanagh 2014b). The project builds on recommendations for a proposed approach for developing Eco-SGV for cadmium provided in MPI (2012) and Cavanagh 2014b) and utilises an added risk approach. However, this project is due to be completed in June 2016, and no Eco-SGVs developed in this project are available for use.

In the interim, the 'minimal risk' and 'serious risk' guideline values for the protection of ecological receptors developed by Cavanagh and O'Halloran (2006) and Cavanagh (2006) can be used. Minimal- and serious-risk values are aimed at nominal protection of 95% and 50% respectively, of species in an ecosystem from detrimental effects. The toxicity endpoint data used were the No observed effect concentration (NOEC) or concentration at which 10% of the test population were affected (EC10). A more detailed description of the methodology used and a summary of the basis for the Eco-SGVs established for the trace elements considered by Cavanagh and O'Halloran (2006) and Cavanagh (2006) are provided in Appendix 2.

Background soil concentrations in relation to Eco-SGVs

Cavanagh and O'Halloran (2006) also discuss the significance of background soil concentration in relation to determining Eco-SGVs. These authors noted that different approaches for the setting of regulatory values to account for background concentrations of naturally occurring substances have been used internationally, for example, Dutch agencies have adopted an 'added-risk' approach whereby a nominal amount (based on toxicity test data in which metals are assumed to be fully bioavailable) is added to the background concentration (which is assumed to not be bioavailable) to yield the final soil criteria (Crommentuijn et al. 1997; Verbruggen et al. 2001). This approach is used in REACH guidance (ECA 2008) on conducting a chemical safety assessment for naturally occurring substances, and more recently in Australia for the development of Ecological Investigation Levels (EIL, SCEW 2010). Canadian agencies set the soil quality guideline to the geological background concentration where the derived value is below that concentration (CCME 2006). The US EPA does not include background concentrations in their derived values. but states that the background concentration should be taken into consideration when undertaking a risk assessment (US EPA 2005a–e). In New Zealand's *Timber Treatment Guidelines* (MoH & MfE 1997), background concentrations replaced derived values where these were lower than the derived concentrations (e.g. arsenic).

In the SRGVs developed for Auckland Council, derived values were replaced with a relevant background concentration if the derived values were lower. This approach was adopted 'for consistency with existing approaches in New Zealand' (Cavanagh & O'Halloran 2006).

As noted above, the added risk approach is proposed for use in the Envirolink Tools project, although the toxicological limits are yet to be determined. Table 3 shows the different added risk Eco-SGVs developed using the serious risk guideline values and minimal risk guideline values from Cavanagh and O'Halloran (2006) and Cavanagh (2006), and the 95th percentile background concentrations (excluding the subgroup with elevated Cr and Ni concentrations).

Table 3 Revised Eco-SGVs using an added-risk approach and 95th percentile background concentration and MRGV and SRGV from Cavanagh and O'Halloran (2006) and Cavanagh (2006).

Element	Ecological Serious risk value (SRGV) (mg/kg)	Ecological Minimal risk value (MRGV) (mg/kg)	95th percentile background concentration (mg/kg)	Added risk Eco-SGV	
				MRGV (mg/kg)	SRGV (mg/kg)
Arsenic	22	12	8.6	20.6	30.6
Cadmium	12	1	0.7	1.7	12.7
Chromium	68	55	85	140	153
Copper	135	45	40.4	85.4	173.8
Lead	100	60	26.4	86.4	126.4
Nickel	110	35	53.4	88	133
Zinc	200	180	128	308	328

The significance of adding the background concentration to the derived value depends on whether the background concentration is markedly higher or lower than the derived ecological risk guideline. Considerations of background concentration are different for

human health compared with ecological health. Whereas the bioavailability of naturally elevated concentrations (or even legacy contamination) of trace elements is likely to be markedly reduced compared with fresh contamination, and soil ecosystems are considered to have adapted to these elevated concentrations of trace elements, an increased risk is still considered to be posed to human health.

Protection of human health

The Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (hereafter referred to as the NES) came into effect on 1 January 2012. The NES includes soil contaminant standards (SCS_{health}) for Cd. Soil contaminant standards are contaminant concentrations in soil at or below which people's direct exposure to soil is judged to be acceptable because any adverse effects on human health are likely to be minor.

The methodology for the derivation of the soil contaminant standards is outlined in MfE (2011a). Briefly, an SCS_{health} is the soil contaminant concentration that does not result in a specified intake (tolerable intake) of a contaminant being exceeded under a given exposure scenario and taking account of background exposure, e.g. diet. The basis for tolerable intakes (called Toxicological intake values in MfE 2011a, b) and background exposures used to derive the SCS_{health} for different contaminants are set out in MfE (2011b). Five generic land use scenarios are considered (rural residential, residential, high-density residential, recreation, and commercial/industrial/outdoor worker), which utilise standardised receptors and exposure parameters.

Different methodologies are used to develop SCS for non-threshold and threshold contaminants. SCS for non-threshold contaminants are derived to ensure that the potential for detrimental effects arising from contaminant intake does not exceed a risk of 1 in 100 000. They are based on exposures of children and adults (residential scenarios) or adults only (commercial scenarios) and averaged over a lifetime

Cleanfills, managed fills, and protection of ecological receptors

Cleanfills provide a useful means to dispose of uncontaminated material, and reduce the amount of material potentially disposed to landfill. General guidance on managing cleanfills is available (MfE 2002), with more recent guidance provided in the Land Disposal Technical Guidelines that were released for public consultation in July 2013 (WasteMINZ 2013), with final release anticipated in May 2015 (Paul Evans, CEO WasteMINZ, pers. comm.). In the latter guidelines, landfills are classified into four types:

- Class 4 Landfill – Cleanfill
- Class 3 Landfill – Managed/Controlled Fill
- Class 2 Landfill – Construction and Demolition Landfill or Industrial Waste Landfill
- Class 1 Landfill – Municipal Solid Waste Landfill or Industrial Waste Landfill

Class 4 landfills accept materials such as virgin excavated natural materials (VENM), which include soils, clays, gravels and rocks, and limited amounts of inert manufactured materials (e.g. concrete, brick, tiles) and incidental or attached biodegradable materials (e.g. vegetation). The definition of cleanfill states that 'when discharged to the environment cleanfill material will not have a detectable effect relative to the background', and materials disposed to a Class 4 landfill should pose no immediate or future risk to human health or the environment. This definition is similar to that provided in MfE (2002), in which cleanfill is defined as being 'material that when buried will have no adverse effect on people or the environment' and is free of hazardous substances (MfE 2002).

Waste acceptance criteria (WAC) for chemical contaminants for class 4 landfills in WasteMinz (2013) are proposed to be local background concentrations. Appendix A in WasteMinz (2013) provides WAC for class 4 landfills, using the regional background concentrations for Auckland and Greater Wellington as examples.

A Class 3 landfill accepts managed/controlled fill materials, which are considered to be predominantly cleanfill materials, but also other inert materials, and soils with chemical contaminants in excess of local background concentrations, but with specified maximum total concentrations (Table 4.1 in WasteMinz 2013). There is no indication of what the expectation is for the future land use of those sites, and therefore what might form the basis of acceptable criteria. Appendix B in Wasteminz (2013) provides a list of WAC that have been derived from a variety of sources, although not all would be considered to be protective of ecological receptors.

Some regional councils have used a combination of background concentrations and Eco-SGVs to develop criteria for cleanfill (Cavanagh 2013b). In developing these criteria, several factors are taken into consideration, including:

- regulatory and statutory definitions of cleanfill, hazardous substances, and contaminated land
- natural concentrations of various trace elements in soil
- the range of soil guideline values that are available, their status, and what they are designed to protect.

Consistent with other cleanfill guidance, a fundamental driver is that cleanfill should not create contaminated land, noting that the RMA definition of contaminated land encompasses both human and ecological receptors (e.g. soil invertebrates, plants and soil microbial health). Further, the RMA specifies that land that has a hazardous substance that 'is *reasonably likely* to have *significant adverse effects* on the environment [italics added]' is contaminated land.

As such, cleanfill should not create contaminated land in relation to the most sensitive receptor class at a site. This decision also needs to allow an adequate margin for sample heterogeneity (spatial differences in concentrations), sampling error, and analytical error, to avoid inadvertent deposition of contaminated soil. Conversely, it would not be justifiable to reject material for cleanfill disposal that contained less of a naturally occurring hazardous substance than is usually found as part of the upper end of the local background range.

Cleanfill thresholds therefore should:

- be less than the guideline values that could be used to define significant adverse effects for the most sensitive receptor class
- allow an adequate margin for error, so that exceeding a cleanfill threshold by a minor margin will not inadvertently allow deposition of contaminated soil
- not be lower than the 95th percentile of the local background range.

Further, where a guideline indicating significant adverse effects was greater than the 95th percentile of the local background, the approach adopted was to develop criteria half-way between these two figures, and in so doing provide a 'buffer' to ensure that exceeding a cleanfill threshold by a minor margin does not inadvertently allow for deposition of contaminated soil . This approach provides assurance that the future use of land will not be impacted.

In the context of providing a 'buffer' to ensure cleanfills do not become contaminated for ecological receptors, it may be appropriate to use the added risk approach, based on minimal risk values and an upper estimate of background concentration, or alternatively, use a measure of the central tendency of background soil concentrations (median or mean) and the SRGV. There is no 'right' answer as to which approach should be used; rather, consensus should be reached. These values should be compared with relevant human health standards or guidelines to determine whether ecological or human receptors are the most sensitive. For the current work, the Eco-SGVs derived by Cavanagh and O'Halloran (2006) and Cavanagh (2006) were used to derive soil concentration criteria based on protection of ecological receptors. These values are based on the use of NOEC or EC10 toxicity data, whereas the proposed approach for the Envirolink Tools project used LOEC or EC30 toxicity data (Cavanagh 2014), thus providing a conservative approach to the protection of ecological receptors.

5.4 Interim cleanfill criteria for the Tasman/Nelson region

Interim cleanfill criteria for the Tasman/Nelson region based on protection of ecological receptors were determined using the two approaches suggested above, specifically the addition of the minimal risk criteria to an upper estimate of the background concentration (the MRGV added risk criteria) and the addition of the SRGV to a measure of the central tendency of background soil concentrations (median was used as this tends to provide a more robust estimate of central tendency for non-normally distributed data) (the SRGV added risk criteria). The criteria based on the addition of the minimal risk criteria to an upper estimate of the background concentration (MRGV added risk criteria) are typically lower than the criteria based on the addition of the SRGV to a measure of the central tendency of background soil concentrations (median) (Table 4), and thus are proposed as a conservative measure for the protection of ecological receptors.

Interim cleanfill criteria based on protection of human health were based on the SCS_{health} for the rural-residential exposure scenario (MfE 2011a), where available, as cleanfills may often be located in rural locations. For Ni, the current UK SGV for nickel (Environment Agency 2009), selected following MfE (2011c), was used to provide a human health criterion. In some cases the criteria based on protection of human health are lower than those based on

protection of ecological receptors (e.g. added risk-SRGV and MRGV for As are higher than the SCS for rural residential land use, Table 4). In this case, SGVs for the protection of human health should be given greater weight than Eco-SGVs.

The soil guideline values considered, estimates of background soil concentrations, and derived cleanfill criteria are shown in Table 4.

Table 4 Soil guideline values (mg/kg) considered in the development of cleanfill criteria, estimates of background soil concentrations, and derived potential cleanfill criteria

Element	Human health guidelines NES SCS_{health} rural-residential	Biosolids Guidelines[1]	Ecological Serious Risk Value (SRGV)[2]	Ecological Minimal Risk Value (MRGV)[2]	95th percentile background concentration[3]	Median background concentration[3]	Derived added risk values		Derived human health criteria[6]
							MRGV[4]	SRGV[5]	
Arsenic	17[7]	20	22	12	8.6	5	20.6	27	12.8
Cadmium	0.8[7]	1	12	1	0.7	0.24	1.7	12.2	0.75
Chromium	>10 000[7]	600	68	55	85	41	140	109	-
Copper	>10 000[7]	100	135	45	40.4	24.2	85.4	159	-
Lead	160[7]	300	100	60	26.4	13.6	86.4	113	93.8
Nickel	130[8]	60	110	35	53	23	88	133	91.5
Zinc	-	300	200	180	128	72	308	272	-

[1]NZWWA (2003)

[2]Cavanagh and O'Halloran (2006), Cavanagh (2006)

[3]From Table 1; values for Cr-lo and Ni-lo are used.

[4] 95th percentile background concentrations and MRGV.

[5] Median background plus SRGV.

[6]Equidistant between human health guideline value and 95th percentile background concentration.

[7]National Environmental Standard SCS_{health} for rural residential exposure scenario (MfE 2011).

[8]UK Residential SGV for nickel (EA 2009).

6 Summary

Preliminary estimates of the upper limit of background concentrations for selected trace elements in the Tasman/Nelson region are shown in Table 5. These upper limits are based on the 99th percentile for the individual analytes rather than the 95th upper confidence level of the 95th percentile concentrations (95UCL), which was used in Cavanagh (2014b), as the 95UCL often equalled the maximum measured concentration. This is likely due to the low number of samples. The estimates for Cd are recognised to overestimate background concentrations of Cd, as all sites will have had phosphate fertiliser applied, and thus some input of Cd. Given the concentration range of other trace elements, it was considered unlikely that there was any significant contribution from anthropogenic sources, with the exception of Pb, for which the presence of lead-based paint should be discounted as the reason for elevated concentrations at selected sites.

Analysis of existing soil sample data showed that elevated concentrations of Cr and Ni were present in soils mainly belonging to the Recent soil order. Extraction of additional data from three spatial databases (S-Map, LRIS, Q-Map) did not yield any identifiable features that delineated the sites with elevated Cr and Ni. However, mapping of the data revealed that sites with elevated Cr and Ni are clustered in a particular location, which may indicate a geological clustering.

The identification of a cluster of sites with elevated concentrations suggests this general area should be treated differently when determining background soil concentrations. A further rationale for treating this area separately is that the added-risk Eco-SGVs based on previously determined background concentrations are lower than soils showing elevated concentrations of Cr. This implies that if higher background concentrations were used to establish cleanfill criteria across the whole region, i.e. based on the inclusion of the sites with elevated Cr and Ni, detrimental effects could occur if those cleanfills were located in regions with lower concentrations, which is where cleanfills are currently located.

The derived cleanfill criteria for trace elements in Tasman/Nelson are intended to prevent the formation of contaminated land for the most sensitive receptor (ecological receptors or people). Using the ‘added risk’ risk approach, criteria were developed for the non-elevated region of the Tasman/Nelson region for the protection of ecological receptors. Specifically, criteria were developed by the addition of the MRGV to the 95th percentile background concentration determined from sites not contained within an area with elevated Cr and Ni. Criteria were also developed based on protection of human health, using relevant human health criteria, notably NES SCS_{health} for rural-residential exposure scenarios and the current UK residential SGV for Ni (Environment Agency 2009). The lowest criteria should be used to ensure that the future land use of any site that receive excess soil from horticultural/orchard sites is not restricted.

Table 5 Recommended interim cleanfill criteria for the Tasman/Nelson region.

Element	No. of sites	99th percentile	Cleanfill criteria based on protection of ecological receptors	Cleanfill criteria based on protection of human health	Recommended cleanfill criteria
As[1]	47	11	20.6	12.8	12
Cd	29	0.90	1.7	0.75	0.75
Cr-hi[2]	8	183	*	*	-
Cr-lo[3]	21	93.5	140	-	140
Cu	43	41.5	85.4	-	85
Pb	48	33	86.4	93.2	86
Ni-hi[2]	8	274.4	*	*	-
Ni-lo[3]	21	53.4	88	91.5	88
Zn	29	141.5	308	-	300

[1]Arsenic concentrations excluding the elevated point (18 mg/kg)

[2]Subgroup of sites with seemingly naturally elevated Cr and Ni concentrations

[3]Subgroup of sites with seemingly normal concentrations of Cr and Ni

*Given the small number of samples in these groups, no cleanfill criteria are given.

7 Recommendations

- Additional sampling is required to develop more robust estimates of background soil concentrations in the Tasman/Nelson region. Specifically, additional sampling is required on sites of agricultural land use on Ultic soils, and exotic and indigenous forest, and scrub and shrubland sites that are primarily located on Brown, Ultic, Podzol and Melanic soils. Sampling at locations across the region where anthropogenic input of trace elements is not expected would also provide additional data to support the development of more robust estimates of background soil concentrations.
- Further sampling should be undertaken in the vicinity of the locations with identified elevated Cr and Ni to better delineate the region of elevated concentrations, and/or further geological information should be sought to identify the extent of the area likely to contain elevated Cr and Ni.
- Eco-SGVs should be updated to reflect recent recommendations on methodological approach and any recent data, and then used to derive criteria.

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Appendix 1 –Data from individual sampling sites

Table A1 Summary of trace element concentrations (mg/kg) and additional information for individual soil quality monitoring sites (data provided by Tasman District Council)

TDC Site No	Year	Soil series	Soil Order	Landuse classification	General Landuse	Detailed Landuse	Concentration (mg/kg)						
							As	Cd	Cr	Cu	Pb	Ni	Zn
16	2009	Takaka	Recent	Dairy	pasture	Dairy	8.9	0.55	66	30	15	48	76
17	2009	Uruwhenua	Brown	Dairy	pasture	Dairy	7.1	0.62	36	17	12	11	37
18	2009	Anatoki	Recent	Dairy	pasture	Dairy	5.2	0.6	17	13	12	17	35
19	2009	Ikamatua	Brown	Dairy	pasture	Dairy	11	0.73	48	23	11	30	86
20	2009	Puramahoi	Brown	Dairy	pasture	Dairy	5.3	0.56	43	27	19	23	130
21	2009	Motupipi	Brown	Dairy	pasture	Dairy	5.5	0.66	32	27	12	24	78
22	2009	Pisgah	Ultic	Drystock	pasture	Beef	7.9	0.33	46	16	17	22	66
23	2009	Hamama	Brown	Dairy	pasture	Dairy	11	0.52	85	20	12	56	54
1	2010	Karamea	Recent	Dairy	Pasture	Dairy	7	0.46	41	26	14.7	30	96
2	2010	Ikamatua	Brown	Dairy	Pasture	Dairy	18	0.39	95	36	15.7	32	61
3	2010	Onahau	Podzol	Dairy	Pasture	Dairy	<2	0.5	4	8	2.8	<2	5
5	2010	Mapua	Ultic	Perennial	Orchard	apples	21	0.23	11	58	119	6	75
6	2010	Waimea	Recent	Horticulture	Market garden	vegetables	4	0.18	187	31	9.4	280	73
7	2010	Waimea	Recent	Drystock	Rehabilitated site, pasture	sheep	5	<0.10	86	42	10.7	113	72
8	2010	Waimea	Recent	Drystock	Rehabilitated site, pasture	sheep	3	0.1	90	23	9.3	121	60
9	2010	Ikamatua	Brown	Drystock	Rehabilitated site pasture	beef	4	<0.10	24	12	11.9	18	45
24	2010	Karamea	Recent	Perennial	Orchard	kiwifruit	8	0.54	59	23	19	28	121

TDC Site No	Year	Soil series	Soil Order	Landuse classification	General Landuse	Detailed Landuse	Concentration (mg/kg)						
							As	Cd	Cr	Cu	Pb	Ni	Zn
25	2010	Takaka	Recent	Perennial	Orchard	kiwifruit	7	0.18	70	29	10.1	33	70
26	2014	Motukara	Recent	Drystock	pasture	sheep and beef	6	0.14	59	16	9.7	51	54
27	2014	Waimea	Recent	Perennial	orchard	apples	4	0.46	89	36	16.8	91	146
28	2014	Waimea	Recent	Dairy	pasture	dairy	4	0.96	88	41	11.7	88	125
29	2014	Braeburn	Gley	Drystock	pasture	beef	< 2	< 0.1	8	4	11.6	3	17
30	2014	Dovedale	Brown	Drystock	pasture	beef	<2	0.2	7	3	4.4	3	21
31	2014	Redwood	Recent	Arable	crop	lucerne	4	0.16	114	29	10.8	160	77
32	2014	Wai iti	Recent	Horticulture	Market garden	vegetables	4	0.19	130	29	9.9	200	68
33	2014	Redwood	Recent	Perennial	viticulture		5	0.24	111	39	9.3	126	103
34	2014	Motupiko	Recent	Perennial	viticulture		4	0.17	24	18	12.9	16	67
35	2014	Cotterell	Recent	Perennial	viticulture		4	0.16	63	19	10.6	53	73

Table A2 Summary of selected information extracted from S-MAP, LRIS (Land Resources Information System) or QMAP for individual soil quality monitoring sites.

Site No	Year	Landuse for mapping	Rockclass of fines (SMAP)[1]	Rock (LRIS)[2]	Soils series (LRIS)	Soil order (LRIS)	Rock Group (QMAP)	Rock Class (QMAP)
16	2009	Dairy	Hs	Al	Karamea	Recent	gravel	clastic sediment
17	2009	Dairy	Hs	Al	Puramahoi	Brown	gravel	clastic sediment
18	2009	Dairy	Hs	Al	Hamama	Brown	gravel	clastic sediment
19	2009	Dairy	Hs	Al	Hamama	Brown	gravel	clastic sediment
20	2009	Dairy	Hs	Al	Puramahoi	Brown	gravel	clastic sediment
21	2009	Dairy	Hs	Al	Puramahoi	Brown	gravel	clastic sediment
22	2009	Drystock	Gr	Al	Hamama	Brown	gravel	clastic sediment
23	2009	Dairy	Hs	Al	Hamama	Brown	gravel	clastic sediment
1	2010	Dairy		Al	Karamea	Recent	gravel	clastic sediment
2	2010	Dairy		Al	Ikamatua	Brown	gravel	clastic sediment
3	2010	Dairy		Al	Onahau	Podzol	gravel	clastic sediment
5	2010	Perennial		Cw	Mapua	Ultic	gravel	clastic sediment
6	2010	Horticulture		Al	Waimea	Recent	gravel	clastic sediment
7	2010	Drystock		Al	Waimea	Recent	gravel	clastic sediment
8	2010	Drystock		Al	Waimea	Recent	gravel	clastic sediment
9	2010	Drystock		Al	Ikamatua	Brown	gravel	clastic sediment
24	2010	Perennial	Hs	Al	Karamea	Recent	gravel	clastic sediment
25	2010	Perennial	Hs	Al	Karamea	Recent	gravel	clastic sediment
26	2014	Drystock		Al	Waimea	Recent	gravel	clastic sediment
27	2014	Perennial		Al	Waimea	Recent	gravel	clastic sediment
28	2014	Dairy		Al	Waimea	Recent	gravel	clastic sediment
29	2014	Drystock		Al	Dovedale	Recent	gravel	clastic sediment
30	2014	Drystock		Al	Dovedale	Recent	gravel	clastic sediment
31	2014	Arable		Al	Waimea	Recent	gravel	clastic sediment
32	2014	Horticulture		Al	Waimea	Recent	gravel	clastic sediment
33	2014	Perennial		Al	Waimea	Recent	gravel	clastic sediment
34	2014	Perennial		Al	Waimea	Recent	gravel	clastic sediment
35	2014	Perennial		Al	Dovedale	Recent	gravel	clastic sediment

[1] Hs – Hard sedimentary sandstone [2] Al = alluvium; Cw = weakly consolidated conglomerate

Table A3 Summary of trace element concentrations (mg/kg) for individual sampling sites (data provided by consultants via Tasman District Council) and selected information for these sites extracted from LRIS (Land Resources Information System) or QMAP. (No S-MAP data was available for these sites).

Site No	Location	Concentration (mg/kg)							Toprock (LRIS)[1]	Soil order (LRIS)	Soil series (LRIS)	Rock group (QMAP)	Rock class (QMAP)
		As	Cd	Cr	Cu	Pb	Ni	Zn					
TDC001	Motueka	4			26	16.3			Al	Recent	Riwaka	gravel	clastic sediment
TDC002	Motueka	7			36	17			Al	Recent	Riwaka	gravel	clastic sediment
TDC003	Motueka	5.6			24.2	25.8			Al	Brown	Hau	gravel	clastic sediment
TDC004	Mariri	7			17	25			Cw	Ultic	Mapua	gravel	clastic sediment
TDC005	Ruby Bay	1.25			8.5	14.3			Cw	Ultic	Mapua	gravel	clastic sediment
TDC006	Tasman	5			30	16.1			Cw	Ultic	Mapua	gravel	clastic sediment
TDC007	Ruby Bay	7			21	58			Cw	Ultic	Mapua	gravel	clastic sediment
TDC008	Ruby Bay	1			5.5	9.55			Cw	Ultic	Mapua	gravel	clastic sediment
TDC009	Mapua	1.25			5.9	8.9			Cw	Ultic	Mapua	gravel	clastic sediment
TDC010	Mapua	5			0	20.9			Cw	Ultic	Mapua	gravel	clastic sediment
TDC011	Mapua	5.7			0	38			Cw	Ultic	Mapua	gravel	clastic sediment
TDC012	Bronte	3			6	16.3			Cw	Ultic	Mapua	gravel	clastic sediment
TDC013	Kina Peninsula	1			21	12.2			Cw	Ultic	Mapua	gravel	clastic sediment
TDC014	Tahuna	3.5	0.05	25.5	36.5	17.4	16.5	84.5	town	town	town	sand	clastic sediment
TDC015	Richmond	6			0	13.5			Al	G	Richmond	gravel	clastic sediment
TDC016	Nelson	1.5			18.5	9.5			Al	G	Richmond	sand	clastic sediment
TDC017	Richmond	6			29	19.9			Al	G	Richmond	gravel	clastic sediment
TDC018	Richmond	6.25			27.3	27.9			Al	G	Richmond	gravel	clastic sediment
TDC019	Nelson	6.25			72	20.6			Al	Brown	Ranzau	gravel	clastic sediment
TDC020	Richmond	6			41	25			Al	Brown	Ranzau	gravel	clastic sediment
TDC021	Richmond	4.9			0	20.72			Al	Brown	Ranzau	gravel	clastic sediment
TDC022	Richmond	4.6			0	19.5			Al	Brown	Ranzau	gravel	clastic sediment
TDC023	Appleby	5			32	15.1			Al	Brown	Ranzau	gravel	clastic sediment
TDC024	Silty clay	4			32	27			Cw	Ultic	Mapua	gravel	clastic sediment
TDC025	Silty clay	3.3			13	24			Cw	Ultic	Mapua	gravel	clastic sediment
TDC026	Alluvial gravel	2	0.05	21.3	31.5	8.8	17	76.8	Al	G	Richmond	sand	clastic sediment

[1] Al = alluvium; Cw = weakly consolidated conglomerate

Appendix 2 – Eco-SGV derived for Auckland Regional Council

The following text is taken from Cavanagh (2013b).

Data that were eligible to be used in the derivation of guideline values by the Canadian, Dutch and US agencies were used in the derivation of Eco-SGVs for Auckland Regional Council. For data from other sources, toxicity tests conducted in soil with a pH between 4 and 8 (where reported) were used. NOEC or EC10 values derived by appropriate statistical methods were considered to be equivalent values and were preferentially used to derive soil guideline values. Data from all sources were compiled and cross-checked to ensure multiple entries of the same data did not occur. In some instances, different endpoints were reported for the same data. For example, MATC were reported in the US EPA Eco-SSL documents, while Lofts et al. (2004) reported NOECs or EC10 data, or calculated (when not reported by the original authors) EC10 data.

Where limited NOEC or EC10 data were available or reported but other toxicity data were available, these data were converted to NOEC data as follows (adapted from Traas 2001):

- The highest reported concentration, not significantly different from the control at $P < 0.05$ is regarded as the NOEC, provided it is not the highest tested concentration.
- The highest tested concentration showing 10% effect or less is considered to be the NOEC if no statistical evaluation is possible
- If only a LOEC is reported:
    - 10<LOEC<20% effect: NOEC = LOEC/2
    - 20<LOEC<50% effect: NOEC = LOEC/3
    - LOEC = 50% effect: NOEC = LOEC/10
- If a maximum acceptable toxicant concentration (MATC) is reported: NOEC =MATC/2

Where various toxicity data were available based on the *same* toxicological endpoint for one species these values were averaged by calculating the geometric mean. If toxicity data based on different toxicological endpoints for one species were available, the lowest were selected. For example, if for a given species a NOEC of 10 mg/kg is reported for growth and a NOEC of 50 mg/kg for reproductive effects, the NOEC for growth effects was used to derive the soil guideline values. If more than one value for the same parameter is available, the lowest value was determined on the basis of the geometric mean.

Normalisation of the available data (e.g. to a standard organic matter content or standard soil) was not undertaken, although this may refine the derived values.

For the current work, plants and soil invertebrates were the primary ecological receptors considered most relevant for protection in an urban environment. Higher animals were not considered, as their visits to a contaminated site are typically transient, making it difficult to estimate potential exposure. Given their primary role in the proper functioning of soil ecosystems, microbial processes were also considered. However, there were a number of uncertainties regarding the interpretation and ecological significance of some data, and values derived for several chemicals appeared to be unrealistically low compared with normal background concentrations. As such, soil guideline values based on microbial processes were

not used to establish proposed guideline values. Instead, soil criteria based on protection of microbial processes were compared with those based on protection of plants and soil invertebrates and if the data indicated any adverse effect on microbial processes could occur, then specific reference to this effect was made. It was also noted that US EPA do not derive Eco-SSLs using microbial processes as they consider the microbial data are insufficient and the interpretation of test results too uncertain to establish thresholds for risk-screening purposes. Other agencies have adopted variable approaches to the inclusion of microbial function in the derivation of soil guideline values.

Two guideline values were derived for each contaminant – minimal-risk and serious-risk soil guideline values – to indicate the range of effects of soil contaminant concentrations. The minimal-risk value is aimed at nominally protecting 95% of species from detrimental effects of contaminants, while the serious-risk value is aimed at nominally protecting 50%. The influence of the choice of data endpoints on the derived soil guideline value is shown in Figure A1.

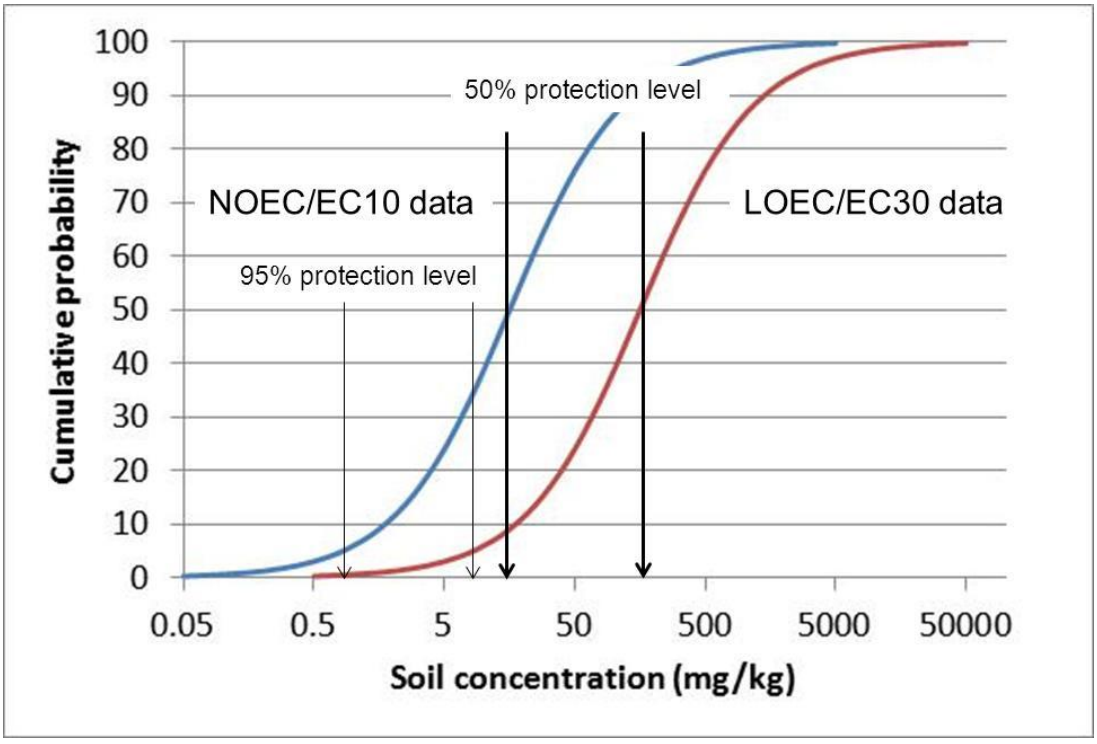

Figure A1 The influence of different toxicity endpoints (NOEC/EC10, LOEC/EC30) and protection levels on final derived soil guideline values using a statistical extrapolation approach.

The methodology used to derive soil guideline values for the protection of on-site ecological receptors in this report follows the conventional approach of using statistical extrapolation methods where sufficient data are available, and assessment factors where insufficient data are available.

The statistical extrapolation method used here is based on that used by Dutch agencies and specifically that in Verbruggen et al. (2001), who use the same method as that used in the derivation of the Dutch Intervention values (Lijzen et al. 2001), except that the statistical

extrapolation method of Aldenberg and Jaworska (2000) is used. This approach assumes a log-normal distribution, as opposed to a log-logistic distribution, of toxicity data.

Table 6 Magnitude of assessment factors used in the current study

Criteria	Data type	Factor
Minimal-risk soil acceptance criteria[1]	L(E)C50 short-term toxicity tests	1000
	NOEC for one long-term toxicity test	100
	NOEC for additional toxicity tests of two trophic levels	50
	NOEC for additional long-term toxicity tests of three trophic levels	10
Serious-risk soil acceptance criteria[2]	Geometric mean of L(E)C_{50}	10
	Geometric mean of NOECs	1

[1] Based on European Commission (2003)

[2] Based on Verbruggen et al. (2001)

The setting of generic soil acceptance criteria for metals is complicated by the variability in bioavailability, and hence toxicity, and background concentrations in different soil types. Different approaches for the setting of regulatory values to account for background concentrations of naturally occurring substances are used internationally. Tor consistency with existing approaches in New Zealand, Cavanagh and O'Halloran (2006) and Cavanagh (2006) adopted the practice of replacing derived values with a relevant background concentration where the derived values are less than the background concentration. Specifically, the maximum measured background concentration as determined in a study of inorganic elements in soils in the Auckland Region (ARC 2001) became the soil criterion, where this is higher than the derived value. Where there is a difference between volcanic and non-volcanic soils, we use the concentration for non-volcanic soils as the proposed value, with a note that higher background concentrations may be relevant for volcanic soils. Selection of the maximum measured concentration as the relevant background concentration is largely a pragmatic decision, recognising that it is impractical to require remediation to below-background concentrations, and that derived values are typically conservative as they are based on total metal concentrations, which usually overestimate the potential toxicity of metals in soil.

Table 7 Serious risk, adapted from Cavanagh and O'Halloran (2006) and Cavanagh (2006)

Contaminant	Derived value		Method[1]	Background range[2]		Proposed criteria	
	MRGV[3]	SRGV[4]		Non-volcanic	Volcanic	MRGV[3]	SRGV[4]
Arsenic	0.2	22	A	0.4–12		12	22
Cadmium	1	12	S	<0.1–0.65		1	12
Chromium	0.8	68	A	2–55	3–125	55	68
Chromium VI	0.007	20	A	-		0.007	20
Mercury	0.7	65	A	<0.03–0.45		0.7	65
Copper	12	135	S	1–45	20–90	45	135
Lead	6	100	S	<1.5–60		60	100
Nickel	1	110	A	0.9–35	4–320	35	110
Zinc	45	200	S	9–180	54–1160	180	200

[1]Derivation method – A – assessment factor; S – statistical extrapolation; [2]ARC (2001); [3]Minimal risk guideline value; [4]Serious risk guideline value

The following limitations apply to the derived guideline values:

- The limited data available for arsenic, nickel, chromium and mercury mean less confidence is placed in those values.
- There was a paucity of data relating to New Zealand soils or organisms.
- Data obtained from review articles are subject to potential errors and differences in interpretation and/or translation of the original papers by those reviewers.
- Data may exist that we did not obtain. New or different data could result in changes to the derived values.
- Insufficient data meant it was not possible to account for the influence of soil properties on bioavailability and hence toxicity.

Arsenic

Volcanic and non-volcanic soils in the Auckland Region show a mean background concentration of arsenic of <8 mg/kg with individual soils ranging from 0.4 to 12 mg/kg (ARC 2001).

As insufficient data were available to use the preferred statistical-extrapolation method for derivation of soil guideline values for species, the assessment-factor approach was used. Fifty-three datapoints for species, which yielded one NOEC for wood lice, two NOECs for earthworms, 16 NOEC from plants,, and 23 datapoints for four microbial processes were available. Derivation of the minimal-risk guideline value was based on the lowest derived NOEC (2 mg/kg for rice) divided by an assessment factor of 10. This produces a guideline value of 0.2 mg/kg, which is below the background concentration of arsenic. The maximum measured background concentration of arsenic in Auckland soils (12 mg/kg, ARC 2001)

therefore becomes the minimal-risk guideline value. The serious-risk guideline value for arsenic is based on the geometric mean of the available NOEC values.

As sufficient data were available on microbial processes, guideline values based solely on these were also calculated for comparison. Twenty-three datapoints from four different microbial processes were used to derive the proposed minimal-risk and serious-risk soil guideline values of 16 mg/kg and 140 mg/kg, respectively. These values are higher than the proposed guideline values, which confirms that microbial processes will be protected.

Minimal-risk guideline value: 12 mg/kg

Serious-risk guideline value: 22 mg/kg

Cadmium

In the Auckland Region concentrations of cadmium in volcanic soils range from <0.1 to 0.65 mg/kg (median 0.27; mean 0.23) and in seven other soil types from <0.1 to 0.46 mg/kg (medians <0.1–0.18; means 0.08–0.19) (ARC 2001).

Sufficient data were available for species to use statistical extrapolation to derive guideline values. Two hundred and thirty three datapoints were available, yielding 14 NOECs from six different invertebrate orders and 14 NOECs from plants.

Sufficient data were available on microbial processes to use statistical extrapolation. Ninety-six datapoints from 14 different microbial processes were used to derive proposed minimal-risk and serious-risk soil guideline values of 6 mg/kg and 86 mg/kg, respectively. These values are higher than those derived for protection of species, hence protection of on-site soil organisms will also provide protection of microbial processes.

Minimal-risk guideline value: 1 mg/kg

Serious-risk guideline value: 12 mg/kg

Chromium

In the Auckland Region, chromium concentrations in seven non-volcanic soil types ranged from 2.2 to 52.3 mg/kg, (median 8–16.9; mean 11.1–20.7) (ARC 2001). Higher concentrations were observed in volcanic soils, with concentrations ranging from 3.6 to 124 mg/kg (median 61.3, mean 48.5 mg/kg) (ARC 2001).

Total chromium guideline values are based primarily on toxicity studies that utilise Cr III but are intended to protect soils for which Cr VI is a small component of the total mixture. Insufficient data were available to use the preferred statistical-extrapolation method for derivation of soil guideline values for species, so the assessment-factor approach was used. NOEC data were available for only two taxonomic groups (plants and earthworms; seven species) thus an assessment factor of 50 is applied to the lowest NOEC (43 mg/kg). This gives rise to a guideline value (0.86 mg/kg) below background concentrations. Therefore the maximum measured background concentration of chromium in non-volcanic Auckland soils (55 mg/kg; ARC 2001) becomes the minimal-risk guideline value. The serious-risk guideline

value of 68 mg/kg is based on the geometric mean of the available NOEC values (20 datapoints). Higher guideline values, based on the background concentration, would be appropriate for some volcanic soils.

As sufficient data were available on microbial processes, guideline values based solely on these were also calculated for comparison. Fifty-six datapoints from six different microbial processes were used to derive the proposed minimal-risk and serious-risk soil guideline values of 28 mg/kg and 140 mg/kg, respectively. The minimal risk-criteria are lower than background concentrations, which may suggest some effects may be occurring on microbial systems. The serious risk value is higher than the proposed serious-risk guideline value, which indicates microbial processes will be protected from serious harm.

Minimal-risk guideline value (non-volcanic soil): 55 mg/kg

Serious-risk guideline value (non-volcanic soil): 68 mg/kg

Copper

In the Auckland Region, concentrations of copper in volcanic soils range from 20 to 90 mg/kg (median 48.5; mean 44.5) and in non-volcanic soils from 1 to 45 mg/kg (medians 3.3–19.3; means 6.3–15.5) (ARC 2001).

Sufficient data were available for species to use statistical extrapolation to derive guideline values. One hundred and twenty-nine datapoints were available, yielding 17 NOECs from four different invertebrate orders, and 11 NOECs from plants. The proposed minimal-risk guideline value is below background concentrations of a number of soils in the Auckland Region, so the maximum measured background concentration for non-volcanic soils in Auckland (ARC 2001) becomes the minimal-risk guideline value. A higher guideline value, based on the background concentration, would be appropriate for some volcanic soils.

Sufficient data were available on microbial processes to use statistical extrapolation. Seventy-two datapoints from eight different microbial processes were used to derive proposed minimal-risk and serious-risk soil guideline values of 0.4 mg/kg and 63 mg/kg, respectively. These values are lower than those derived for species; hence it is possible that microbial processes will be affected at the proposed soil guideline values.

Minimal-risk guideline value (non-volcanic soil): 45 mg/kg

Serious-risk guideline value: 135 mg/kg

Lead

In the Auckland Region the median and mean lead concentrations in volcanic and non-volcanic soils range from 5.7 to 22.6 mg/kg and 6.6 to 28.4 mg/kg, respectively, with Quaternary soils typically containing the higher concentrations (ARC 2001). The concentrations in individual soils range from <1.5 to 60.2 mg/kg (ARC 2001).

Sufficient data were available for species to use statistical extrapolation to derive the two soil criteria. One hundred and thirty-four datapoints were available, yielding eight NOECs from

seven different invertebrate orders, and 11 NOECs from plants. The derived minimal-risk guideline value (6 mg/kg) is below the background concentration of lead, so the maximum measured soil concentration becomes the minimal-risk guideline value. Some volcanic soils may have higher background concentrations (ARC 2001).

Sufficient data were available on microbial processes to use statistical extrapolation. Fourteen datapoints from five different microbial processes were used to derive proposed minimal-risk and serious-risk soil guideline values of 180 mg/kg and 400 mg/kg, respectively. These values are higher than those derived for protection of species, hence protection of on-site soil organisms will also provide protection of microbial processes.

Minimal-risk guideline value: 60 mg/kg

Serious-risk guideline value: 100 mg/kg

Nickel

Nickel concentrations in the Auckland Region range from 0.9 to 35 mg/kg (median 7.1) in non-volcanic soils and from 4 to 320 mg/kg (median 118) in volcanic soils (ARC 2001).

Forty-three datapoints, yielding five NOECs from two invertebrate orders (earthworms and collembolan), and nine NOECs from plants, were available, which were insufficient for the preferred statistical-extrapolation method. Therefore, the assessment-factor approach was used. Nine datapoints from four different microbial processes were also considered. Derivation of the minimal-risk guideline value was based on the lowest available NOEC (10 mg/kg for *Quercus rubra*) divided by an assessment factor of 10. This gives rise to a value of 1 mg/kg, which is below the background soil concentrations in Auckland. As such, the maximum background concentration in non-volcanic soils becomes the minimal-risk guideline value. A higher guideline value, based on the background concentration, would be appropriate for some volcanic soils. The serious-risk guideline value was based on the geometric mean of the available NOECs.

As sufficient data were available on microbial processes, guideline values based solely on microbial processes were also calculated for comparison. Nine datapoints from four different microbial processes were used to derive the proposed minimal-risk and serious risk soil guideline values of 16 mg/kg and 104 mg/kg, respectively. These values are values are lower than the proposed guideline values, and it is possible that some impacts on microbial processes may occur.

Minimal-risk guideline value (non-volcanic soils): 35 mg/kg

Serious-risk guideline value: 110 mg/kg

Zinc

In the Auckland Region, concentrations of zinc range from 54.5 to 1160 mg/kg (median 247; mean 252) in volcanic soils and from 9.2 to 179 mg/kg (median 52.1; mean 58.7) in non-volcanic soils (ARC 2001).

Sufficient data were available for species to use statistical extrapolation to derive guideline values. One hundred and thirty datapoints were available, yielding 10 NOECs from four invertebrate orders, and six NOECs from plants. The derived minimal-risk guideline value is below background concentrations of several soils in the Auckland Region, so the maximum background concentration in non-volcanic soils becomes the minimal-risk guideline value. A higher value, based on the background concentration, would be appropriate for some volcanic soils.

Sufficient data were available on microbial processes to use statistical extrapolation. Seventy-four datapoints from eight different microbial processes were used to derive proposed minimal-risk and serious-risk soil guideline values of 15 mg/kg and 170 mg/kg, respectively. These values are lower than those derived for species; hence it is possible that microbial processes will be affected at the proposed guideline values.

Minimal-risk guideline value: 180 mg/kg

Serious-risk guideline value: 200 mg/kg