
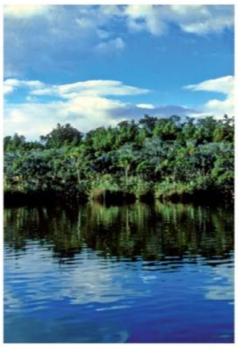

Cleanfill criteria for the Marlborough District

Envirolink Advice Grant: 1295-MLDC86





Landcare Research
Manaaki Whenua

Cleanfill criteria for the Marlborough District

Jo Cavanagh

Landcare Research

Prepared for:

Marlborough District Council

15 Seymour Street (Seymour Square)
PO Box 443
Blenheim 7201
New Zealand

June 2013

Landcare Research, Gerald Street, PO Box 69040, Lincoln 7640, New Zealand,
Ph +64 3 321 9999, Fax +64 3 321 9998, www.landcareresearch.co.nz

Reviewed by:	*Approved for release by:*
Ian Lynn Scientist Landcare Research	Chris Phillips Portfolio Leader Realising Land's Potential

Landcare Research Contract Report: LC 1579

Disclaimer

This report has been prepared by Landcare Research for Marlborough District Council. If used by other parties, no warranty or representation is given as to its accuracy and no liability is accepted for loss or damage arising directly or indirectly from reliance on the information in it.

Contents

Summary

Project and Client

- This report reviews both the current approach for developing cleanfill criteria for trace elements in the Marlborough region and existing soil monitoring data for trace elements, and also considers recent recommendations for the development of Eco-SGVs in New Zealand (MPI 2012, Appendix D) to provide recommendations on the further development of cleanfill criteria. This project was undertaken for Marlborough District Council between May and June 2013 with funding from Envirolink (Small Advice Grant MLDC86).

Objectives

- To provide recommendations on the further development of cleanfill criteria in the Marlborough Region

Methods

- Review of the existing approach to derive cleanfill criteria, including the derivation of soil guideline values to protect ecological receptors (Eco-SGVs).
- Analysis of existing soil monitoring data, including the use of spatial databases (S-Map, LRI and Q-Map) to extract additional information on the current soil monitoring sites.

Results

- Cleanfill criteria in Marlborough have been developed to ensure the land does not become contaminated for the most sensitive receptor. These criteria have been based largely on the concentration equidistant between previously determined background concentrations for individual trace elements, and previously derived serious risk guideline value (SRGV) for the protection of ecological receptors. The human health value used for Ni (50 mg/kg) has been superseded and the new value (130 mg/kg) should be used in revising cleanfill criteria. Additionally, Soil Contaminant Standards (SCS) used in the National Environmental Standard should be used.
- An "added-risk" approach, by which Eco-SGVs based on toxicity data are added to background concentrations, is increasingly being used both nationally and internationally to derive final Eco-SGVs. Different approaches may be used to provide a "buffer" to ensure cleanfills do not become contaminated land for ecological receptors. For example, the Eco-SGVs based on a higher protection level (e.g. minimal risk guideline values) could be added to 95^{th} percentile background concentrations. An alternative may be to use a measure of the central tendency of background soil concentrations (median or mean) and the SRGV. There is no definitive "right" answer, but consensus should be reached as to what provides the appropriate level of protection.
- Analysis of existing soil monitoring data showed that 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 of Cr and Ni. However, these sites are clustered in alluvial valley fill draining regions associated with quartz reef mineralisation in schist, and ultrabasic rocks, e.g. in the Pelorus, Wakamarina, Linkwater, Fabians Creek areas.

- Revised Cleanfill criteria were developed for the non-elevated region of Marlborough using updated human health soil guideline values, and added risk Eco-SGVs derived by the addition of median background concentrations and SRGV (below).

Element	Recommended interim Cleanfill criteria (mg/kg)
Arsenic	12
Cadmium	0.9
Chromium	88
Copper	147
Lead	92
Nickel	75
Zinc	260

Recommendations

- Based on currently available data, background soil concentrations should be determined for two regions within the Marlborough District – the region where elevated Cr and Ni are found, and outside this region. The boundaries of these regions need to be fully determined.
- 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.
- Eco-SGVs should be updated to reflect recent recommendations on methodological approach and any recent data.

1 Introduction

Cleanfills provide a useful means to dispose of uncontaminated material, and reduce the amount of material potentially disposed to landfill. However, there is no national guidance on establishing appropriate criteria for trace elements in waste disposed to cleanfills. One approach originally developed for the Waikato region has been used by Marlborough District Council. This approach includes the use of background concentrations of trace elements and soil guideline values derived to protect ecological receptors (Eco-SGV) for Auckland regional council (Cavanagh and O'Halloran 2006, Cavanagh 2006). Recently it has been found that some background concentrations of selected substances exceed the Eco-SGVs, posing challenges in establishing cleanfill criteria to ensure an appropriate level of environmental protection.

This report reviews the current approach for developing cleanfill criteria, reviews existing soil monitoring data for trace elements and considers recent recommendations for the development of Eco-SGVs in New Zealand (MPI 2012, Appendix D) to provide recommendations on the further development of cleanfill criteria for the Marlborough District. This project was undertaken with funding from Envirolink (Advice Grant MLDC86).

2 What is cleanfill?

General guidance on managing cleanfills is available (MfE 2002). This guideline provides a broad definition of material acceptable for cleanfill as being "material that when buried will have no adverse effect on people or the environment". Cleanfill material includes virgin natural materials such as clay, soil and rock, and other inert materials such as concrete or brick that are free of:

- combustible, putrescible, degradable or leachable components
- hazardous substances
- products or materials derived from hazardous waste treatment, hazardous waste stabilisation or hazardous waste disposal practices
- materials that may present a risk to human or animal health such as medical and veterinary waste, asbestos or radioactive substances
- liquid waste.

A key point here is that such materials are free from hazardous substances. Trace elements are naturally occurring substances that can be hazardous if present in high concentrations, thus there is a need to establish appropriate concentrations so that material accepted for cleanfill does not contain hazardous concentrations of trace elements.

3 Objectives

This project will provide an appropriate approach to establish cleanfill limits and ensure these limits guarantee an appropriate level of environmental protection by:

- Review basis for establishing existing cleanfill criteria for trace elements, including the ecological soil guideline values used to develop the criteria
- Analysis of current soil quality monitoring data

4 Methods

The basis for establishing existing cleanfill criteria for trace elements in Marlborough, including the ecological soil guideline values used to develop the criteria was reviewed.

Analysis of existing soil monitoring data was undertaken using spatial databases (S-Map, LRI and Q-Map) to extract additional information on the current soil monitoring sites, and mapping.

5 Results

5.1 Marlborough District Council guideline values for cleanfills

Current cleanfill criteria for trace elements developed for the Marlborough District are based on adaptation of an approach used in the Waikato region. In developing these criteria, several factors were 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.

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, RMA specifies that land that has a hazardous substance that "is *reasonably likely* to have *significant adverse effects* on the environment..." is contaminated land.

As such, cleanfill should not create contaminated land in relation to the most sensitive receptor class at a site. However, any decision on cleanfill that takes this as a principle 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.

The guidelines considered in the development of MDC cleanfill included:

- Guidelines mostly based on human health values, and are already derived from a general methodology outlined by the Ministry for the Environment (e.g. MfE & MOH 1997).
- Guidelines that could be regarded as ‘fill up to’ limits for various trace elements in soils suggested by the authors of the Biosolids Guidelines (NZWWA 2003). Although these guidelines are an industry document (published by the New Zealand Water and Waste Association), they also come with endorsement from three Ministries (Environment, Health and Agriculture and Forestry).
- Two reports written by Landcare Research for the Auckland Regional Council (Cavanagh & O’Halloran 2006; Cavanagh 2006). These include a suggested risk-based methodology to derive guidelines for the protection of ecological receptors, and suggested ‘minimal risk’ and ‘serious risk’ guideline values (SRGVs) for eight trace elements. These guidelines nominally provide protection for 95% and 50% of ecological receptors, respectively. The SRGV values used to develop cleanfill criteria conform to the RMA definition of contaminated land as requiring a reasonable likelihood of significant adverse effects.

The development of the cleanfill criteria predated the development of the *National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health* (the NES), which came into effect 1 January 2012. Table 1 outlines the guidelines considered in the development of the Marlborough District Cleanfill guidelines, and relevant Soil Contaminant Standards (SCS_{health}) from the NES. The 95th percentile of background concentration was determined from State of the Environment monitoring undertaken to 2010.

Table 1 Soil guideline values (mg/kg) considered in the development of Cleanfill guidelines in the Marlborough District, and Soil Contaminant Standards (SCS_{health}) for selected land use

Element	**Residential soils screening**[1]	**Biosolids Guidelines**[2]	**Ecological serious risk value (SRGV)**[3]	**95th percentile background concentration**[4]	**NES SCS_{health}**[5]	
					Rural residential	**Residential**
Arsenic	30	20	22	4.3	17[6]	20
Cadmium	1	1	12	0.2	0.9	3
Chromium	600	600	68	26	>10 000 (260)[7]	>10 000 (490)[7]
Copper	370	100	135	18	>10 000	>10 000
Lead	300	300	100	14	160	210
Nickel	50	60	110	19	-	-
Zinc	7000	300	200	78	-	-

[1] Pre-NES, includes human health and ecological health National Environmental Standard

[2] NZWWA (2003)

[3] Cavanagh & O'Halloran (2006), Cavanagh (2006)

[4] Based on SOE monitoring undertaken over 2007 and 2008, n=46

[5] National Environmental Standard MfE (2011)

[6] Based on 99th percentile of a compiled national dataset on background concentrations of arsenic

[7] Cr VI

"-" – No value available.

A summary of the cleanfill guidelines developed for Marlborough, and the basis for the derivation, is shown in Table 2.

Table 2 Marlborough District Council cleanfill guidelines

Element	Cleanfill criteria (mg/kg)	Basis	Comment
Arsenic	13	Equidistance between Marlborough 95th percentile of background and SRGV	
Cadmium	1	Protection of trade (food safety) NZWWA 2003	Also equates to Tier 2 of the Tiered Fertiliser management System (MAF 2011)
Chromium	47	Equidistance between Marlborough 95th percentile background and SRGV	
Copper	77	Equidistance between Marlborough 95% percentile and SRGV	
Lead	57	Equidistance between Marlborough 95th percentile of background and SRGV	
Nickel	34	Equidistance between Marlborough 95th percentile and UK SGV of 50 mg/kg (DEFRA 2002)	The UK SGV of 50 mg/kg has been superseded, and current value is 130 mg/kg (Environment Agency 2009)
Zinc	139	Equidistance between Marlborough 95th percentile background and SRGV	

As can be seen from the above Table, the majority of current cleanfill criteria are based on the concentration equidistant between the 95th percentile background concentration and the SRGV determined by Cavanagh and O'Halloran (2006) and Cavanagh (2006).

5.2 Soil guideline values for the protection of ecological receptors (Eco-SGV)

The Eco-SGVs determined by Cavanagh and O'Halloran (2006) and Cavanagh (2006) were derived by:

- compiling toxicity data for soil invertebrates, plants and microbial processes – data were obtained primarily from regulatory sources and review articles
- using statistical extrapolation, where sufficient data were available, or assessment factors.

'Minimal risk' and 'serious risk' guideline values were derived based on protection of soil invertebrates and plants, and a check was undertaken to establish whether any effects on microbial processes would occur at the specified concentrations. 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 in this report are provided in Appendix 1.

Background soil concentrations

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). 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 state 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).

A new approach

Since this the report undertaken in 2006, the development of soil guideline values for the protection of ecological receptors has increasingly used an 'added-risk approach' for naturally occurring elements. This approach was proposed by Crommentujin et al. (1997) and assumes that species are fully adapted to the natural background concentration and therefore only the anthropogenic added fraction should be regulated or controlled. This approach is used in the Netherlands in the development of intervention values for managing contaminated land, in REACH guidance (ECA 2008) on conducting a chemical safety assessment for a naturally occurring substances, and more recently in Australia for the development of Ecological Investigation Levels (EIL, SCEW 2010).

The Australian methodology or an adaptation has also been proposed for use in New Zealand to develop soil guideline values for cadmium (MPI 2012). This revised approach has implications for the approach currently used to develop cleanfill criteria – particularly those based on being equidistant between 95th percentile background concentrations and the SRGV derived by Cavanagh and O'Halloran (2006) and Cavanagh (2006). Table 3 shows the different added risk Eco-SGVs developed using the serious risk guideline value and minimal risk guideline values, the 95th percentile background concentrations, and compares those with the current cleanfill criteria.

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), and current cleanfill criteria.

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		Current cleanfill criteria (mg/kg)
				SRGV (mg/kg)	MRGV (mg/kg)	
Arsenic	22	12	4	26	16	13
Cadmium	12	1	0.2	12	1.2	1
Chromium	68	55	26	94	81	47
Copper	135	45	18	153	63	77
Lead	100	60	14	114	74	57
Nickel	110	35	19	129	54	34
Zinc	200	180	78	278	258	139

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. Further it should be noted that some added risk Eco-SGVs are higher than relevant human health guideline values (e.g. added risk-SRGV for As is higher than the SCS for rural residential land use). 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 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.

Considerations of background concentration are different for human health compared with ecological health. Although the bioavailability of naturally elevated concentrations (or even legacy contamination) of trace elements is likely to be markedly reduced compared with freshly contaminated soil ecosystems are considered to have adapted to elevated concentrations of trace elements, while risk is still posed to human health.

5.3 Defining background concentrations

The primary motivation for undertaking the current project is because recent soil sampling found seemingly naturally occurring elevated concentrations of Cr and Ni. Cavanagh (2013) recently provided a review on determining background soil concentrations of contaminants, and the factors that need to be considered. 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. Attributable to mineral content derived from parent materials, and influence of soil-forming processes.

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. Referred to as 'normal' concentrations in the UK (DEFRA 2012).

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 Marlborough 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 Cr and Ni, As, Pb (although there is the potential for some historic use of lead arsenate pesticide). There may be some use of products containing Cu (copper-based fungicides), Cd (phosphatic fertilisers), and Zn (facial eczema treatment) on some land-uses that may elevate the concentrations of these trace elements.

Another aspect raised in Cavanagh (2013) was 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. As noted above, the 95^{th} percentile of concentrations from locations under different land use (thus, technically equivalent to baseline concentrations using the above definitions) has been used in the development of cleanfill criteria. In contrast, the 99^{th} percentile concentration of arsenic in soils collected from around the country and thought not to have been affected by anthropogenic activities was used as the SCS for the rural residential land-use scenario in the NES, as the derived value for this scenario was below this concentration. Similarly, the 99^{th} percentile concentration of cadmium in soils collected from around the country and 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 95^{th} percentile is typically used as upper limit for background soil concentrations (see Cavanagh 2013).

The choice of what upper limit is appropriate 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. To prevent the land becoming contaminated it may be more appropriate to use a lower limit.

However, the choice of upper limit may be less significant than the appropriate "grouping" of soils with similar features. Cavanagh (2013) also recommended that more extensive analysis (including the use of spatial tools such as S-Map) of existing data should be undertaken to identify key factors influencing trace elements. In addition a potential useful ultimate goal was the ability to determine background concentrations for 2–4 'domains' for individual chemical substances that are applicable across New Zealand. As such, further analysis of the soil quality monitoring data collected to date was undertaken.

5.4 Investigating elevated Cr and Ni soil concentrations in the Marlborough District

All sites that had elevated soil concentrations of Cr and Ni are associated with active land use; as such the potential exists for the sites to be anthropogenically contaminated with Cr and Ni. However, all sites are under agricultural land use (primarily grazing) and Cr and Ni are not trace elements typically associated with anthropogenic sources of trace elements in agricultural systems (e.g. Cd from phosphatic fertilisers, Zn from facial eczema treatment, Pb and As from historic use of lead arsenate pesticides). It therefore seems unlikely that anthropogenic contamination is the source of these elevated concentrations.

To investigate whether there were any identifiable features of the sites with elevated concentrations of Cr or Ni that could better delineate those locations, information was extracted 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 NZLRI soil fundamental data layers (FSLs), vegetation data layers, and LCDB (land-cover database). The NZLRI (FSL) 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 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 parent material, rock class, and 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 "main rock" for each of the sampling locations were extracted.

All locations for which trace element data had been collected were used, including sites from which soil was taken from 0–7.5 and 0–10 cm depths. This resulted in 195 locations being assessed. While soil concentrations are expected to be marginally higher in samples collected from 0–7.5 cm depth from uncultivated sites, this difference was considered to be negligible in the context of identifying potential reasons for the markedly elevated concentrations of Cr and Ni. The range of concentrations of individual trace elements is shown in Figure 1, while the concentrations of Cr and Ni for individual soil orders are shown in Figure 2.

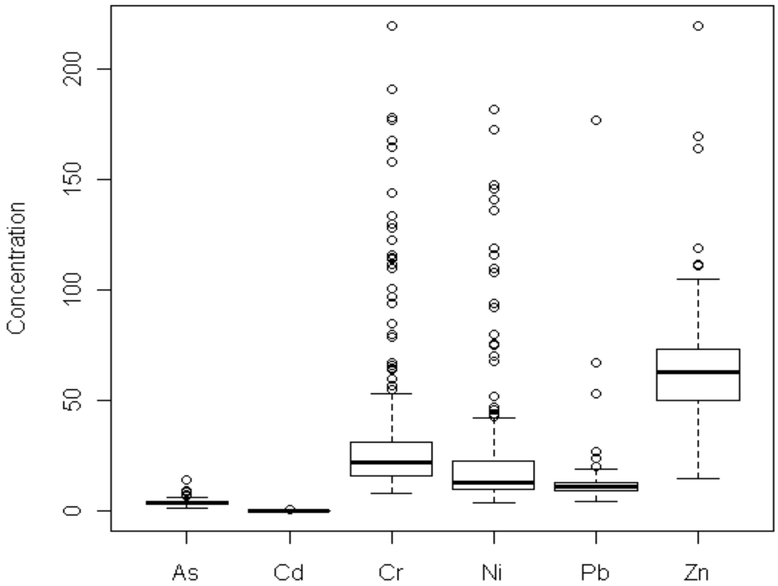

Figure 1 Boxplot showing spread of concentration (mg/kg) for individual trace elements.

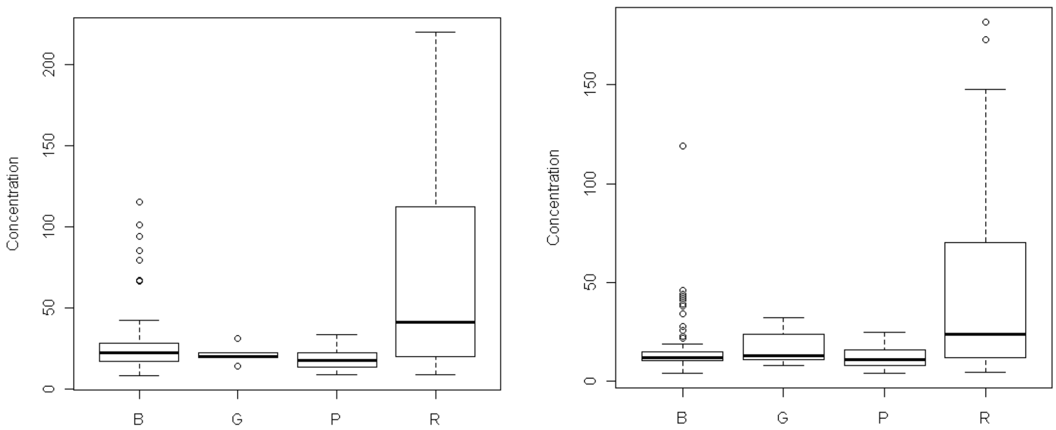

Figure 2 Boxplot of Chromium (left) and Nickel (right) concentrations for each soil order. B – Brown; G – Gley; P – Pallic; R – Recent.

A summary of the data extracted is shown in Table 4. Approximately 36% of sites were included in S-Map; unfortunately none of the sites with elevated concentrations of Cr and Ni were contained within S-Map coverage. As can be seen from Table 4, soils were predominantly from the Brown, Pallic, and Recent soil orders, the rock-type-of-fines was predominantly hard sedimentary sandstone (S-map), and rock was alluvium (LRIS) or gravel

(QMap). Pallic soils showed the greatest variability in the extracted “rock” information, although these rocks are chemically similar and none of these soils showed elevated Cr or Ni. In contrast, soils that showed elevated Cr or Ni were predominantly Recent soils, and all were identified as alluvium (LRIS) or gravels (QMap).

Table 4 Soil order and rock classifications extracted from S-Map, LRI or Q-Map for the Marlborough District Council soil monitoring locations shown in Figure 3

Soil order	Number	‘Rock-type-of-fines’ (S-Map) (number of samples in S-Map)	Rock (LRIS)[1]	Main rock (QMap)
Brown	70	Hard sedimentary sandstone (17)	Al (63), Gw (5), St1(2), St2(1)	Gravel (62), sandstone (5), breccia (1),schist(1) silt(1)
Pallic	55	Hard sedimentary sandstone (18), soft sedimentary sandstone (1)	Al (25), Lo (25), St2(4), Ms(1)	Schist (7), sandstone (5), Conglomerate (6), siltstone (2)
Gley	5	Hard sedimentary sandstone (4)	Al	Silt (2),gravel (3)
Recent	65	Hard sedimentary sandstone (34)	Al (64), riv (1)	Gravel (62),Silt(1), conglomerate 2

[1] Al-alluvium, Gw – greywacke; St1 – semi-schist; St2 – schist; Lo – loess; Ms – mudstone; riv – riverine

Table 5 Soil order and rock classifications extracted from S-Map, LRI or Q-Map for sites with elevated Cr (>65 mg/kg, n=30)[1]

Soil order	Number	‘Rock-class of fine’ (S-Map) (number of samples in S-Map)	Rock (LRIS)	Main rock (QMap)
Brown	8	Na	Al	gravel
Recent	22	Na	Al	gravel

[1] Ni concentrations ranged from 28–182 mg/kg; Na – not available

There are constraints in extracting site-specific data from these databases due to the mapping scales used by the respective systems, that is, 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 case, no notable features for the sites with elevated Cr (and Ni), were evident from data extraction using the above databases (Table 4). However, the spatial clustering of these sites (Fig. 3, which shows sites with Cr >45 mg/kg clustered together) suggests there is likely some reason for these elevated concentrations. Further investigation revealed that the sites with elevated Cr and Ni are clustered in alluvial valley fill draining regions associated with quartz reef mineralisation in schist, and ultrabasic rocks, e.g. in the Pelorus, Wakamarina, Linkwater, Fabians Creek areas. These ultrabasic rocks will have elevated Cr and Ni.

The identification of a cluster of sites with elevated concentrations suggests this general area should be treated differently when determining background soil concentrations, and consequently cleanfill criteria. A further rationale for treating this area separately is that the added-risk Eco-SGV shown in Table 3 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 the locations are in regions with lower concentrations, which is where cleanfills are currently located (Fig. 3).

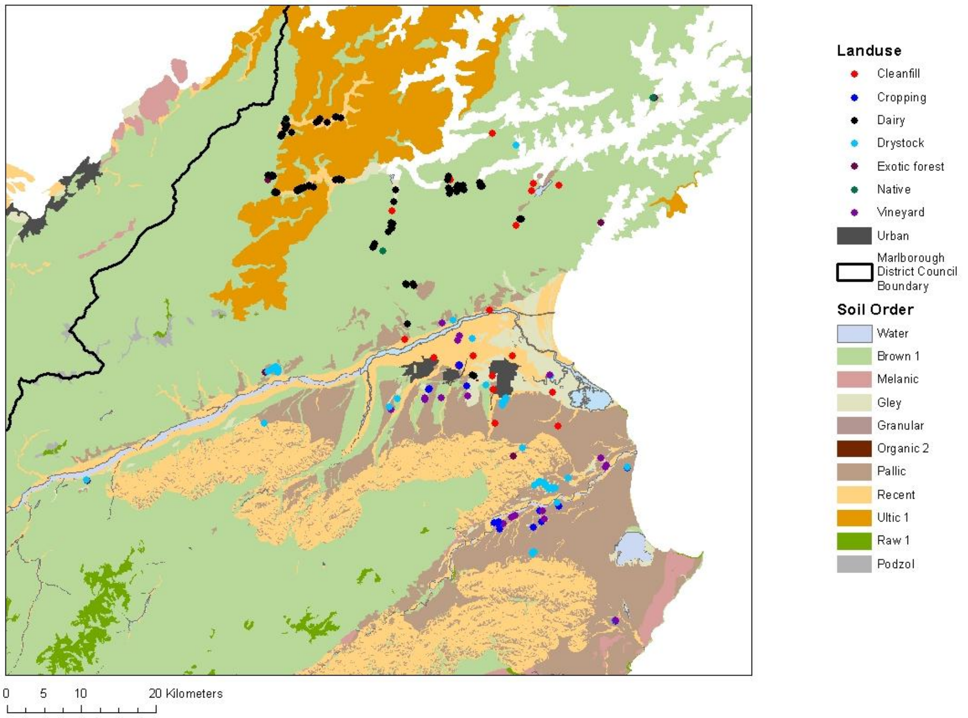

Figure 3 Location of soil monitoring sites with associated land use and current cleanfills, and distribution of soils from different orders across Marlborough.

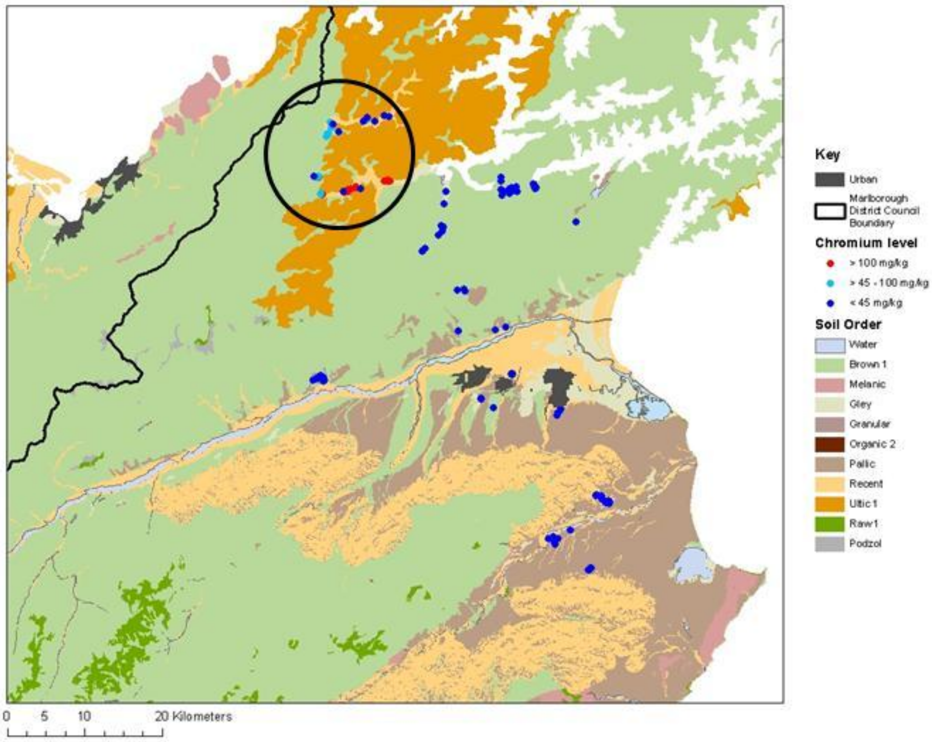

Figure 4 Map showing clustering of sites with elevated (>45–100 mg/kg) or highly elevated (>100 mg/kg) concentrations of Cr.

6 Revised cleanfill criteria

Revised cleanfill criteria were developed for the non-elevated region (i.e. those sites located outside of the area within the circle on Figure 4). 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.

The revised cleanfill criteria were developed using the same general approach as described in section 5.1, notably, all available soil guideline values were taken into account in development of the final criteria, and criteria based on human health were equidistant between 95th percentile concentrations and the human health criteria. The updated human health criteria – namely NES soil contaminant standards (SCS_{health}), and the current UK SGV for nickel (130 mg/kg) – were used as the basis for the derived human health criteria. Criteria based on protection of ecological receptors were determined using the two approaches suggested in section 5.2, specifically the addition of the minimal risk criteria to an upper estimate of the background concentration (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 soil guideline values considered, estimates of background soil concentrations, and derived criteria are shown in Table 6. Estimates of background concentrations of trace elements were made using an updated dataset and include samples taken at 0–7.5 and 0–10 cm depths from all land uses to provide a larger dataset. It should be noted that trace elements in samples collected over 0–7.5 cm depth might be approximately 10% higher than samples collected over 0–10 cm for non-cultivated land (e.g. Cd in phosphatic fertilizers). Given the concentration range of other trace elements, it was considered unlikely that there was any significant contribution from anthropogenic sources. The SCS_{health} for the rural residential exposure scenario were selected as the basis for human health guideline values (MfE 2011a), where available, as cleanfills may often be located in rural locations. The current UK SGV for nickel was used to update the previous value, which was selected following MfE (2011b). The Eco-SGVs derived by Cavanagh and O'Halloran (2006) and Cavanagh (2006) were used to derive criteria based on protection of ecological receptors; however, it should be noted that these values should be updated to reflect recent recommendations on methodological approach and any recent data. Additionally, further testing may yield different estimates of background concentrations. As such, these revised cleanfill criteria should be considered provisional.

Table 6 Soil guideline values considered in the development of cleanfill criteria, 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]
							SRGV[4]	MRGV[5]	
Arsenic	17[7]	20	22	12	5.97	3.4	25.4	17.97	11.49
Cadmium	0.9[7]	1	12	1	0.582	0.2	12.2	1.582	0.7
Chromium	>10 000[7]	600	68	55	30	19.6	87.6	85	
Copper	>10 000[7]	100	135	45	22	12	147	67	-
Lead	160[7]	300	100	60	24.7	11.6	111.6	84.7	92.4
Nickel	130[8]	60	110	35	19	10.9	120.9	54	74.5
Zinc	7000[9]	300	200	180	87	59	259	267	-

[1]NZWWA (2003)

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

[3]Determined from current soil quality monitoring dataset, includes samples taken at 0–7.5 and 0–10 cm depths from all land uses to provide a larger dataset. Trace elements in samples collected over 0–7.5 cm depth may be approximately 10% higher than samples collected over 0–10cm for non-cultivated land (e.g. Cd in phosphatic fertilizers). This is primarily applicable for Cd.

[4]Median background plus SRGV.

[5]95th percentile background concentrations and MRGV.

[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).

[9]Previous value.

Table 7 Comparison of recommended interim cleanfill criteria and their basis of derivation with current cleanfill criteria

Element	Current Cleanfill criteria (mg/kg)	Recommended interim Cleanfill criteria (mg/kg)	Comment
Arsenic	13	12	Equidistant between rural residential SCS_{health} and 95th percentile background
Cadmium	1	0.9	Rural residential SCS_{health}
Chromium	47	88	Added risk SRGV
Copper	77	147	Added risk SRGV
Lead	57	92	Equidistant between rural residential SCS_{health} and 95th percentile background
Nickel	34	75	Equidistant between rural residential SCS_{health} and 95th percentile background
Zinc	139	260	Added risk SRGV

7 Summary

Cleanfill criteria for trace elements in Marlborough are intended to prevent the formation of contaminated land for the most sensitive receptor (ecological receptors or people). These criteria have been based largely on the concentration equidistant between the 95^{th} percentile background concentration and the SRGV determined by Cavanagh and O’Halloran (2006) and Cavanagh (2006). Recent recommendations for the development of Eco-SGVs in New Zealand are that an “added-risk” approach is used, whereby derived values, such as those derived by Cavanagh and O’Halloran (2006) and Cavanagh (2006) are added to a relevant background concentration.

Analysis of existing soil monitoring 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 sites with elevated Cr and Ni are clustered in alluvial valley-fill draining regions associated with quartz reef mineralisation in schist and ultrabasic rocks, e.g. in the Pelorus, Wakamarina, Linkwater, Fabians Creek areas.

The identification of a cluster of sites with elevated concentrations suggests this general area should be treated differently when determining background soil concentrations, and consequently cleanfill criteria. A further rationale for treating this area separately is that the added-risk Eco-SGV 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 locations are in regions with lower concentrations, which is where cleanfills are currently located.

Using the “added-risk” risk approach, revised criteria were developed for the non-elevated region of Marlborough for the protection of ecological receptors. Specifically, criteria were developed by the addition of the SRGV to the median background concentration determined from sites not contained within an area with elevated Cr and Ni. These criteria were compared with criteria developed 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), and the lowest criteria were recommended for use.

8 Recommendations

Recommendations for the further development of cleanfill criteria:

- Based on currently available data, background soil concentrations should be determined for two regions within the Marlborough District – the region where elevated Cr and Ni are found, and outside this region. The boundaries of these regions need to be fully determined.
- 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 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.

9 Acknowledgements

Anitra Fraser is thanked for undertaking the data extraction and for developing the maps.

10 References

Aldenberg T, Jaworska J 2000. Uncertainty of the hazardous concentration and fraction affected for normal species distribution. Ecotoxicology and Environmental Safety 46: 48–63.

ARC (Auckland Regional Council) 2001. Background concentrations of inorganic elements in soils from the Auckland Region. Auckland Regional Council Technical Publication 153.

Cavanagh JE, 2006. Development of soil guideline values protective of ecological receptors: Part 2. Landcare Research Contract Report LC0506/079 for Auckland Regional Council.

Cavanagh JE, 2013. Determining background soil concentrations of contaminants for managing land. Envirolink Advice Grant 1251-MLDC83 for Marlborough District Council.

Cavanagh JE, O'Halloran K 2006. Development of soil guideline values protective of ecological receptors. Landcare Research Contract Report LC0506/065 for Auckland Regional Council.

CCME 2006. Protocol for the derivation of environmental and human health soil quality guidelines. Winnipeg, Manitoba, Canada, Canadian Council of Ministers for the Environment.

Crommentuijn T, Polder MD, van de Plassche E 1997. Maximum permissible concentrations and negligible concentrations for metals, taking background concentrations into account. RIVM Report 601501 001. Bilthoven, The Netherlands, National Institute of Public Health and the Environment.

DEFRA (Department of Environment, Food and Rural Affairs and Environment Agency 2002 Overview of the Development of Guideline Values and Related Research. Technical Report CLR 7. Department of Environment, Food and Rural Affairs

DEFRA 2012. Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance. April 2012. Department for Environment, Food and Rural Affairs (DEFRA). HM Government. Available online at: http://www.defra.gov.uk/environment/quality/land/ (accessed March 2013).

ECHA (European Chemicals Agency) 2008. Guidance on information requirements and chemical safety assessment Appendix R.7.13-2: Environmental risk assessment for metals and metal compounds. European Chemicals Agency, Helsinki Finland.

Environment Agency 2009. Soil Guideline Values for nickel in soil. Science Report SC050021. Bristol, UK, Environment Agency.

European Commission 2003. Technical Guidance on Risk Assessment. Part II. EUR20418 EN/2. Brussels, European Commission.

Lijzen JPA, Baars AJ, Otte PF, Rikken MGJ, Swartjes FA, Verbruggen EMJ, van Wezel AP 2001. Technical evaluation of the intervention values for soil/sediment and groundwater. RIVM report 711701 023. Bilthoven, The Netherlands, National Institute of Public Health and the Environment.

Lilburne LR, Webb TH, Hewitt, AE, Lynn IH, de Pauw B 2012. S-map database manual. Internal Landcare Research Report LC478. Lincoln, Landcare Research.

Lofts S, Spurgeon DJ, Svendsen C, Tipping E 2004. Deriving soil critical limits for Cu, Zn, Cd, and Pb: a method based on free ion concentrations. Environmental Science and Technology 38: 3623–3631.

MAF 2011. Cadmium and New Zealand agriculture and horticulture: a strategy for long term risk management. Wellington, Ministry of Agriculture and Forestry.

MfE (2002). A guide to the management of cleanfills. Wellington, Ministry for the Environment.

MoH & MfE 1997. Health and environmental guidelines for selected timber treatment chemicals. Wellington, Ministry for the Environment/Ministry of Health.

MPI 2012. Working towards New Zealand risk-based soil guideline values for the management of cadmium accumulation on productive land. Wellington, Ministry for Primary Industries.

New Zealand Water and Wastes Association 2003. Guidelines for the safe application of biosolids to land in New Zealand. Wellington, New Zealand Water and Wastes Association.

SCEW 2010. Draft national environment protection (assessment of site contamination) Measure Schedule B5b. Methodology to derive ecological investigation levels in contaminated soils. COAG Standing Council on Environment and Water. http://www.scew.gov.au/archive/site-contamination/asc-nepm.html (accessed January 2013).

Traas TP ed. 2001. Guidance document of deriving environmental guideline risk limits. RIVM report 601501012. Bilthoven, The Netherlands, Ministry of Housing, Spatial Planning and the Environment.

US EPA (United States Environmental Protection Agency) 2005a. Ecological soil screening level guidance. OSWER Directive 9285.7-55. Washington, DC. Available at: http://www.epa.gov/ecotox/ecossl/SOPs.htm.

US EPA 2005b. Ecological soil screening level for arsenic. Washington, DC, US EPA.

US EPA 2005c. Ecological soil screening level for cadmium. Washington, DC, US EPA.

US EPA 2005d. Ecological soil screening level for lead. Washington, DC, US EPA.

US EPA 2005e. Ecological soil screening level for dieldrin. Washington, DC, US EPA.

Verbruggen EMJ, Posthmus R, van Wezel AP 2001. Ecotoxicological serious risk concentrations for soil, sediment and (ground) water: updated proposals for first series of compounds. RIVM report 711701020. Bilthoven, The Netherlands, Ministry of Housing, Spatial Planning and the Environment.

Appendix 1 – Eco-SGV derived for Auckland Regional Council

The following text is adapted from Cavanagh and O'Halloran (2006).

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.

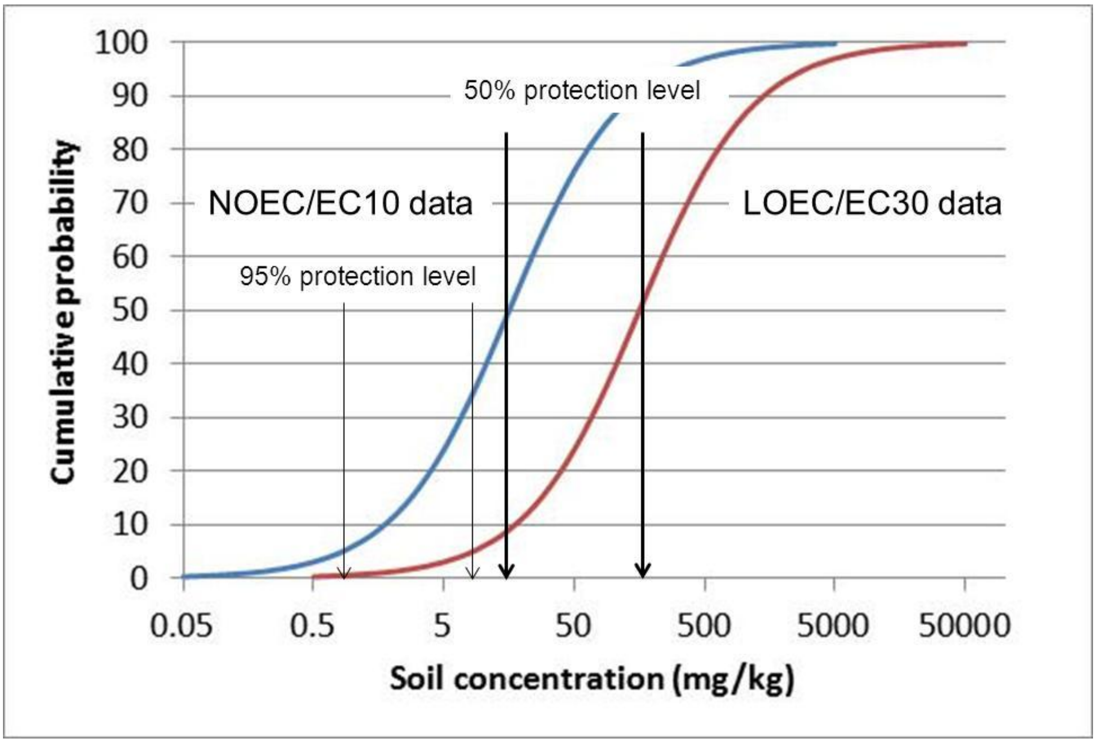

Figure A1 The influence of different toxicity endpoints (NOEC/EC10, LOEC/EC30) and protection levels on final derived soil guideline values using a statistical extrapolation approach.

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 8 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 $L(E)C_{50}$ Geometric mean of NOECs	10 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 9 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