Waikato Regional Council Technical Report 2023/12

Limitations of guidance and disclosure deterrents for historic sheep dip sites

www.waikatoregion.govt.nz
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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Publication November 2025

Doc 26264971

Peer reviewed by:

Dr Megan Balks | Date | August 2023

Approved for release by:

Michelle Begbie | Date | November 2025

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Limitations of Guidance and Disclosure Deterrents for Historic Sheep Dip Sites

A thesis

submitted in partial fulfilment

of the requirements for the degree

of

Master of Science in Earth Sciences at

The University of Waikato

by

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Te Whare Wānanga o Waikato

2022

Abstract

There are an estimated 50,000 historic sheep dip sites in New Zealand. Due to the past use of arsenic and Organochlorine Pesticides (OCPs) sheep dip sites have the potential to be highly contaminated. Historic sheep dip sites are largely unidentified and pose a risk to both human health and the environment. Currently the Ministry for the Environment provides guidance for the identification, investigation and management of sheep dip sites in New Zealand.

The main aims of the research were to evaluate the quality of sheep dip investigations to date and establish the effectiveness of the guidance provided by Ministry for the Environment's *Identifying, investigating and managing risks associated with former sheep-dip sites: A guide for local authorities* and *Contaminated land management guidelines No.1-5.* Another aim was to investigate the willingness of landowners to come forward with their sheep dip sites for investigation, establishing potential deterrents and barriers to disclosure and management of sheep dip locations.

A literature review was conducted to establish potential limitations in Ministry for the Environment's *Identifying, investigating and managing risks associated with former sheep-dip sites: A guide for local authorities*. The literature review identified that there are current research gaps, including limited information regarding historic use of mobile dipping units and dusting machines. Also, the guidelines do not provide accessible information to landowners and local government regarding identification of dip sites, up-to-date cost analysis and reasonable management options.

The methodology consisted of a public survey, study site and a review of Detailed Site Investigations (DSIs) received from various councils across New Zealand. There were a number of limitations including the lack of available study sites, limited responses to the public survey and the small number of DSIs provided. The main limitation which affected all aspects of the methodology was the general unwillingness for members of public to engage.

The results showed that the 72% of the reviewed DSIs were not completed in accordance with Ministry for the Environment's *Contaminated land management guidelines No.1*. The main limitations of the reviewed DSIs included an incomplete site history and limited sampling. The majority of the DSIs did not attempt to fully characterise the potential onsite contamination associated with the sheep dip.

Unfortunately, the results of the public survey are not considered statistically robust due to the small number of respondents. The survey results compared with the literature review indicates that knowledge of the presence of sheep dips, and the historic patterns of their use has been lost over time. A study site was sampled and although arsenic was considered to be found at relatively low concentrations compared to other sheep dip site, dieldrin (2.6 mg/kg) was found to be approximately two times the soil contaminant standard for the protection of

human health (1.1 mg/kg) for the current land use. The number of responses to the survey and public reaction on social media indicated a strong negative reaction to the topic of sheep dip related contamination.

There was a high level of non-compliance with the Ministry for the Environments *Contaminated land management guidelines No.1-5* in the reviewed DSIs. Several factors were considered, including the absence of financial resources available to site owners undertaking investigations, lack of accessible resources in Ministry for the Environments *Identifying, investigating and managing risks associated with former sheep-dip sites: A guide for local authorities* and lack of resources available to staff in local government reviewing the DSIs.

Recommendations include: the need for further research of certain sheep dipping methodologies and their associated contamination; research to establish the potential long term, chronic impacts of sheep dip related contaminant exposure; accessible information to both landowners and local government; consideration of mental health and education in notification processes; and an update to the current Ministry for the Environment Contaminated Site Remediation fund to make it accessible and fit for purpose. These recommendations would encourage positive engagement, thorough site investigations and disclosure of sheep dip locations.

Acknowledgements

I would like to express my gratitude and appreciation to both of my supervisors, Dr Tanya O'Neill (University of Waikato) and Michelle Begbie (Waikato Regional Council). Without their patience, support, invaluable feedback, and guidance this thesis would not have been possible. A big thank you to both Tanya and Michelle for helping me create a meaningful study out of my somewhat crazy ideas. I am also grateful to Waikato Regional Council for their generous support and flexibility that made this research possible.

I would like to thank the owner of the study site mentioned in this report. Your openness and willingness to let me onsite and your honesty during our conversations was invaluable. This dissertation would not have been the same without your support.

Thank you to Cassandra for all the support and helping me find the courage to pursue my masters.

Thank you to Dad, Chelsea and Sue for sending me cat photos, being a source of positivity and for helping me review drafts. Thank you to Tessa for reading more about sheep dips that she would ever care to and helping out on short notice. A final thank you to other friends and family for supporting me through this.

Lastly, a massive thank you to my partner Michael Robinson. You have been endlessly patient and have endured many hours of chats about sheep dips and have been there for the emotional moments.

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Glossary

BGL	Below Ground Level
CSRF	Contaminated Site Remediation Fund
DDT	Dichlorodiphenyltrichloroethane
DSI	Detailed Site Investigation
EcoSGV	Ecological soil guideline values
HAIL	Hazardous activity and industry list (Ministry for the Environment, 2011d).
MfE CLMG No.1	Contaminated land management guidelines No.1: Reporting on contaminated sites in New Zealand (Ministry for the Environment, 2021a)
MfE CLMG No.2	Contaminated land management guidelines No. 2: Hierarchy and application in New Zealand of environmental guideline values (revised 2011) (Ministry for the Environment, 2011c)
MfE CLMG No.3	Contaminated land management guidelines No. 3: Risk Screening System (Ministry for the Environment, 2004)
MfE CLMG No.4	Contaminated land management guidelines No. 4: Classification and information management protocols (Ministry for the Environment, 2006a)
MfE CLMG No.5	Contaminated land management guidelines No. 5: Site investigation and analysis of soils (Ministry for the Environment, 2021b)
NES	Users' guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (Ministry for the Environment, 2012)
NES SCS	Soil contaminant standards from Users' guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (Ministry for the Environment, 2012)
OCP	Organochlorine pesticides
PSI	Preliminary Site Investigation
pXRF	Portable X-ray fluorescence analyser
RMA	Resource Management Act (1991)
Sheep Dip Guidelines	*Identifying, investigating and managing risks associated with former sheep-dip sites: A guide for local authorities* (Ministry for the Environment, 2006b)
SQEP	Suitably qualified and experienced practitioner

Chapter 1
Introduction

1.1 Background

Sheep dips are a major source of contamination in New Zealand, with an estimated 50,000 located across New Zealand (Ministry for the Environment, 2006). The contamination expected from these sites is likely far reaching and the extent of the effects is yet to be fully understood.

Sheep dipping became commonplace during the mid-1800s due to the uprising of a common disease called Scab. Scab is caused by parasitic mites which if left untreated, causes degradation of the sheep's coat and loss of condition. Due to New Zealand's economy heavily relying on large scale sheep farming and wool production, regulations were put in place to control the spread of the disease which resulted in large fines if ignored by farmers.

New Zealand regulations imposed in 1849 (Press, 1878) dictated compulsory sheep dipping. This legislation was in place up until 1993 (Biosecurity Act 1993). A range of pesticides were used over this 144-year period, including those containing arsenic and organochlorine pesticides (OCP's), such as dieldrin, aldrin, dichlorodiphenyltrichloroethane (DDT), and many others (Ministry for the Environment, 2006). The aim of sheep dipping was efficient and cost-effective pest eradication.

Sheep dips evolved over time as farmers tried to find the most efficient and productive means of dipping thousands of sheep at one time. Due to this there were several different styles of sheep dip which have been discussed in Section 2.2. As dips became less commonplace, the visible structure associated with dips were often removed or (as often in the case of plunge/pot dips) infilled. Although a dip may not be visible, the structures will often still be in-situ.

Contaminants typically associated with sheep dipping activities (specifically arsenic and OCPs) have both acute and chronic affects such as potential neurological disorders (Stephens et al., 1995), gastrointestinal upset, an increased risk of cancer and death (World Health Organisation, 2018). New Zealand's *National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health* (NES) is triggered by a proposed change in land use or soil disturbance and implements the requirement to investigate potentially contaminated sites. Investigations are guided by Ministry for the Environment's *Contaminated land management guidelines No.1-5* (MfE CLMGs) and in the case of sheep dips, the Ministry for the Environment's *Identifying, investigating, and managing risks associated with former sheep-dip sites: A guide for local authorities*.

Although it is estimated that there are approximately 50,000 sheep dips in New Zealand (Ministry for the Environment, 2006b), their locations remain largely unknown. Current sheep dip guidelines were published in 2006 and there has been no update to the guide since it was published. The sheep dip guidelines are aimed towards local authorities and are limited in the information that they provide to landowners and contaminated land practitioners for investigations being conducted on sheep dip sites.

1.2 Aims and objectives

The overarching objective of this study was to review existing contaminated land management guidelines and standards to create an understanding of the current state of reporting on sheep dip investigations. This objective was split into the following three aims to establish potential weaknesses or gaps in the current contaminated land management framework:

- Review the standard of reporting to date;
- Review existing sheep dip management guidelines;
- Use the existing CLMGs and sheep dip guidelines to inform the sampling methodology for a sheep dip site;

An additional objective of this study was to identify the potential deterrents and barriers to disclosure and management of sheep dip locations.

Chapter 2

Literature review

2.1 History of sheep dipping in New Zealand

Sheep have been a large part of New Zealand's history since they were first brought to the country in the 1770's to feed whalers on islands off the mainland (Peden & Stringleman, 2015). However, the first sheep farms were not established until the 1840's. The main purpose of these sheep farms was to produce high quality wool for the market (Peden & Stringleman, 2015).

Shortly after the 1840's boom of sheep farming began, the parasite *Psoroptes communis ovis* was identified on sheep imported to New Zealand from Australia and was colloquially named scab (Clark et al., 2008). To prevent major spread of this parasite, an ordinance was brought into effect in New Zealand on the 23rd of August 1849 (13 Victoriae 1849 No 4, 1849).

This ordinance was aptly named the Scab Ordinance (Scab Ordinance of New Munster 1849 13 Vict 4). The main function of this legislation was to control the spread of easily transmissible conditions, specifically scab. Scab is easily spread through direct sheep to sheep contact (Simcock, 2019) and therefore is easily spread through flocks and saleyards. This legislation established the initial controls for the prevention of the spread of scab, for example separation of diseased sheep and destruction of infected carcasses (Scab Ordinance of New Munster 1849 13 Vict 4).

As a follow up to the Scab Ordinance, the Sheep Act of 1878 (amended again in 1886) set a precedent that all sheep infected with scab in New Zealand were to be dipped (Press, 1878). The main outcomes of this act are as follows:

- Chief inspectors of sheep to be appointed in each district
- Any sheep owner that declines inspection of sheep can be fined up to £100 Sheep owners were to be publicly named and shamed if found to be neglecting to dip sheep
- Sheep owners could be fined for not following enforced cleansing orders or neglecting to notify neighbours of scab infestations
- Sheep that were neglected to be dipped would have their fleece branded with a capital 'S', therefore rendering the wool worthless until the sheep were sufficiently treated
- Sheep in any public yards (e.g., saleyards) could be destroyed if found to be infested
- Sheep were to be quarantined if they were to be taken from a scab affected area to what was coined a 'clean' area.

Essentially the Sheep Act 1878 was put in place to create both financial and emotional pressure on those that owned sheep. As sheep owners could have their herds inspected with no notice it became common practice to install plunge dips on sheep farms to prevent fines and destruction of herds. Due to this most, if not all, sheep farms would have had, and may still have, at least one dip onsite. These dips were generally located near a woolshed, or stockyards for ease of use. Larger sheep farms may have multiple dips at different locations across the farm for easier dipping of flocks.

2.2 Types of sheep dips

Although plunge dips (also known as swim-through dips) were the dip of choice noted in the ordinance, there were a number of different dipping options developed over the years further discussed in this section.

2.2.1 Plunge dip

Plunge or swim-through dips were commonly used on farms with large flocks as it was an efficient way of dipping large numbers of sheep (Bigwood et al., 1967). Plunge dips (Figure 2.1 and Figure 2.2) were reasonably expensive to build and maintain due to the need for the sheep to be able to easily enter and safely exit the dip without injury and stopping. Plunge dips also required large quantities of dipping fluid (William Cooper & Nephews, n.d.).

Figure 2.1 Plunge dip in use (Adkin, 1906)

Figure 2.2 **Swim-through dip pictured aerially in 1971 (Local Government Geospatial Alliance, 1971). Sourced from http://retrolens.nz and licensed by LINZ CC-BY 3.0**

Despite their expense, plunge dips were commonly used in New Zealand and consisted of concrete channels filled with dip fluid. The sheep were typically funnelled into the channel and pushed to swim the length of the dip while the farmers pushed their heads into the dipping fluid to ensure full saturation (Figure 2.1). Most often, the sheep travelled in the same direction each time given the layout of the yard structures and so would emerge dripping dip solution from the same end each time, resulting in the accumulation of dip solution in the soil.

2.2.2 Pot dip

According to Duncan (1955) pot dips were another common dip type in New Zealand. The pot dip (Figure 2.3) was the more affordable option for those farmers wishing to build a dip on their farm. However, pot dips did not have the same capacity and ease of use for large flocks compared with plunge dips (Duncan, 1955).

Figure 2.3 Pot dip with sump in foreground (Duncan, 1955)

2.2.3 Spray dip/shower unit

Spray dips (Figure 2.4) were first introduced to New Zealand through their use and testing on the Ruakura Research Station in 1944 (Duncan, 1955). Spray dips were used commonly on farms with relatively small flocks of sheep (Bigwood et al., 1967). The main benefits of spray dips were that less labour was required as the dip could be operated easily by - two to three people and dipping fluid could be recycled through the system, leading to less wastage of product (William Cooper & Nephews, n.d.).

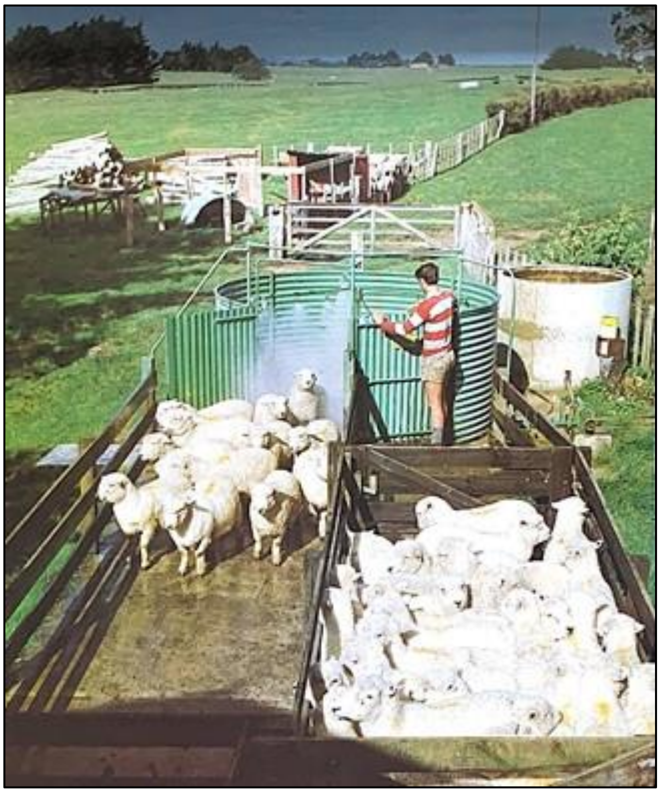


Figure 2.4 **Farmer operating spray unit with sheep exiting into drainage pens (Bigwood et al., 1967)**

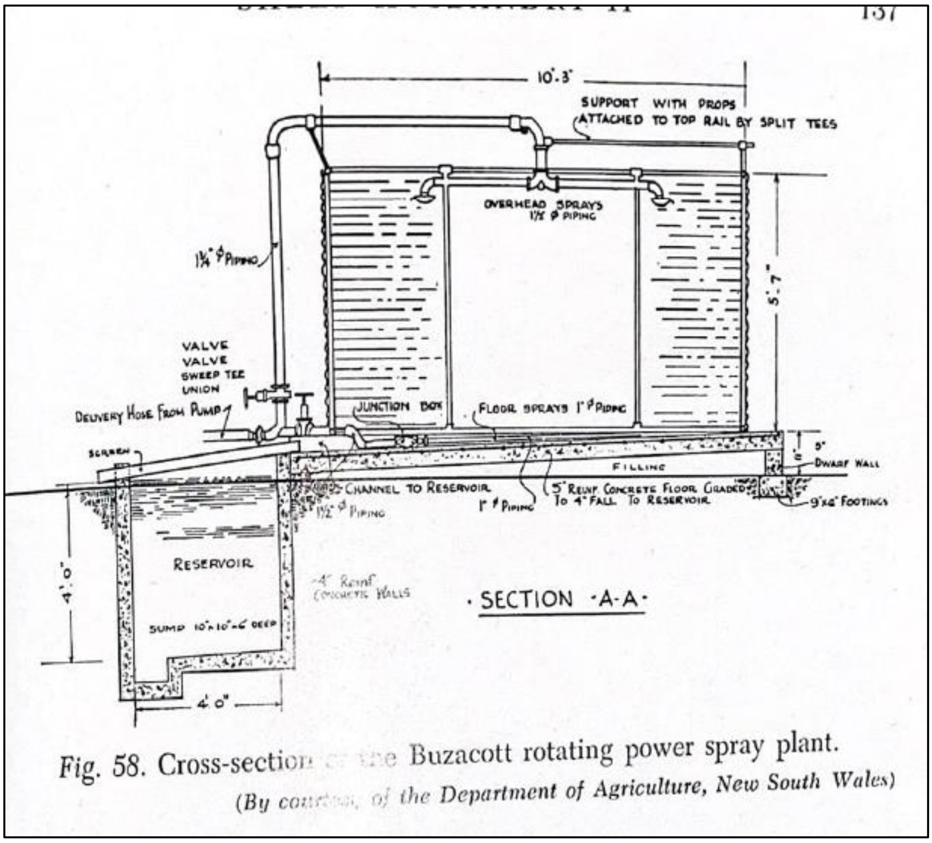


Figure 2.5 **Illustration of Buzacott spray unit (Belschner, 1962)**

Spray dips (Figure 2.5) were a more modern type of dip which appealed to farmers as no excavation was required and they generally used less dip solution. They were commonly circular or rectangular enclosures of corrugated iron where sheep were herded and sprayed with solution. While mobile structures often left no discernible footprint behind, due to their more recent usage/ younger age, they are the most common dip structure still seen on farms today.

2.2.4 Communal dip

Communal or municipal dips were constructed for use by the community. These dips were often constructed in saleyards or railway sidings as they were easily accessible by the local community (Ministry for the Environment, 2006b), therefore, were often located within town limits and potentially close to residential areas. Due to the use profile of these dips (large numbers of sheep moving through dip and therefore more dipping product used and disposed of) higher concentrations of sheep dip contaminants in soil are often assumed at these sites (Ministry for the Environment, 2006b).

2.2.5 Portable/mobile dipping units

Mobile dipping units were also used on farms in New Zealand but are difficult to identify due to their transient nature (often shifted around the farm or brought in by a contractor). Both plunge dips and shower units were available in mobile units (Figure 2.6).

Mobile Plunge Dip In Operation

for a seven ton truck and t
cab came in one part and ha
been attached to a short wh

Loaded on a big trailer it could be mistaken for a small ship and someone has sketched a propellor in chalk on what is apparently the stern of this "vessel." But in reality it is a mobile swim or plunge dip.

Mobile shower dips are now quite common but this is a rather novel development making it possible to carry the plunge dip with the advantages of this form of dipping practice from farm to farm.

Figure 2.6 Newspaper article covering new mobile plunge dip (Press, 1965)

It is unclear when mobile dipping units were introduced in New Zealand but are briefly noted in the sheep dip guidelines (Ministry for the Environment, 2006b). Advertisements for mobile dipping units can be found in historic newspapers (Figure 2.7).

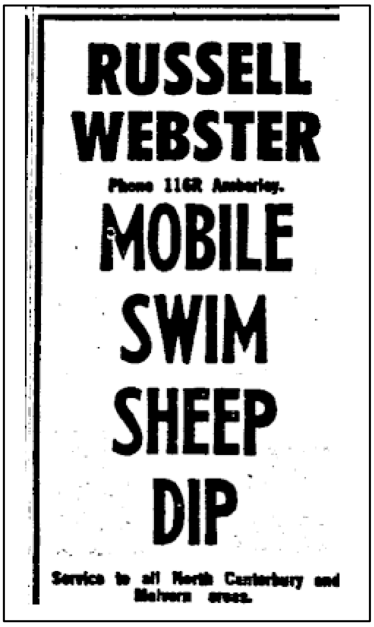


Figure 2.7 Advertisement for a mobile plunge dip in the North Canterbury area (Press, 1969)

As the extent of use of mobile dipping units and the method of dipping fluid disposal is largely unknown, it is unclear how the use of the mobile dipping units may have impacted soil in the areas of operation.

Mobile dipping units were also used on farms in New Zealand, but it is often difficult to identify where and when these units may have been operated due to their transient nature and lack of records. Due to this, mobile dipping units are not often considered when identifying potential sheep dipping sites. There is currently little to no guidance on how to approach a site which may have used a mobile dipping unit or if contamination is likely to be found at sites that used mobile units.

Further research regarding mobile dipping units is required to gain an understanding of the following points to create guidance for sites which may have used mobile dipping units:

- **Timeframe of use of mobile dipping units** – At the time of this research there is currently no readily available guidance on the timeframes of the use of mobile dipping units and it is unclear which chemicals were used. Through historic newspaper advertisements, it is clear that these dips were in use through to the late 1960s (Figure 2.7) indicating the potential presence of arsenic.
- **Prevalence and frequency of use** – It is unclear if mobile dipping units were a commonly used dipping method in New Zealand and if so, how often they were used. Further research is required to assess the prevalence of these dips, if a mobile dip was being used on the same site every dipping season, it could be considered that the area where dipping occurred should be approached in the same manner as permanent dips.
- **Disposal of dipping fluid and dipping practices** – Further to the point above, it is unclear if dipping fluid was disposed of onsite or removed offsite. Regardless, it could be considered that the area of disposal requires identification and to be treated as a potentially contaminated site. It is also unclear where sheep were released to drip dry (as per typical

dipping). If a mobile dip was in use, it could be assumed that infrastructure typically associated with sheep dip sites would not be available (for example, drainage pads upon exiting the dip). Further research is needed to establish how these dips were used and how and where dipping fluid was disposed.

Due to the points above, it is considered that further research is required in order to provide guidance on the best approach to sites that may have used a mobile dipping unit.

2.2.6 Dusting machines

Current sheep dip guidelines do not explore the use of historic dusting machines (Figure 2.8). Dusting machines are briefly mentioned in the sheep dip guidelines but are typically hard to identify in historic aerial imagery due to lack of significant and/or permanent infrastructure in identifiable patterns.

Dusting machines typically used a mixture of filler agents such as mineral oil or ground marble and OCP powder which was typically dieldrin as it was found to have fewer negative effects on stock than others such as DDT (Thomas, 1958). Research into dusting machines and their effectiveness was first reported in 1945 and it was found that the method was relatively effective when used as per the manufacturer's instructions.

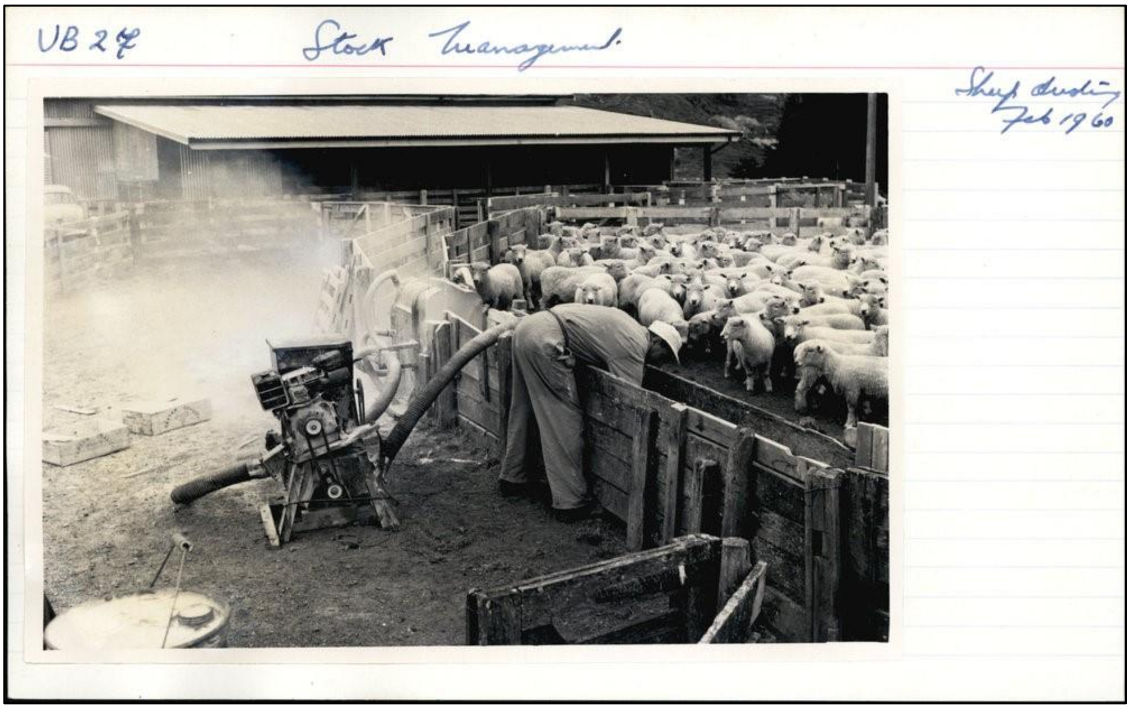


Figure 2.8 Farmer using a dusting machine in the 1960's (Agresearch, 1960). CC-BY 3.0

As of April 1957, although being used in demonstrations and on some farms, sheep dusting was not approved for general use due to concerns over effectiveness but was in the process of being registered as an approved dipping methodology (Press, 1957). By 1959 an amendment to the Stock Act 1908 was created which broadened the definition of 'dip' to include both spray and dusting methodologies (Stock Amendment Act 1959).

2.3 Approved chemicals and advised dip usage over time

A Supplement to the New Zealand Gazette published on the 8th of September 1961 outlined changes to the approved active ingredients of sheep dipping chemicals (Hayman, 1961). The supplement prohibited the use of any dip product with the following active ingredients:

- Aldrin
- Benzene Hexachloride
- DDT
- Dieldrin
- Methoychlor

However, a number of potentially toxic active ingredients remained as approved for use in the treatment of scab, including, but not limited to:

- Arsenic
- Rotenone (commonly called Derris)
- Dioxathion (commonly called Delnav)
- Diazinon

Although arsenic based dips were still authorised and encouraged, implementation of this guidance reduced the amount of OCP's used but anecdotally did not entirely stop the use of these chemicals.

The Biosecurity Act 1993 largely replaced the historic dipping legislation (Biosecurity Act 1993) and modern injectables and pour on pest control measures rapidly eliminated the need for sheep dips from at least the early 1990's (Heath, 1994).

Seemingly random hotspots of contamination around dips are highly likely due to the variability in dipping methodologies and disposal methods. Duncan (1955) specifically advised that the safest and most effective way of disposing of dip packaging is to burn it. This had the potential to leave toxic residues in areas not typically associated with dipping activities. Duncan (1955) also advocates the washing and reuse of metal drums or containers used in the preparation of the dipping fluid due to the valuable nature of these containers. This may also lead to residues entering the soil in seemingly random areas.

In terms of disposal, Duncan (1955) suggested avoiding emptying dipping fluid over pasture wherever possible. Instead, the "gold-standard" was to dig a sump or soakage pit with the capacity to hold at least a dips worth of fluid and to fill it with stones to act as a filter. This would therefore prevent damage to pasture. Although potential risk to groundwater is out of scope of this study, it is an important consideration. A 1996 study of 35 wells in the Waikato Region showed dieldrin exceeded the maximum accepted values for drinking water in two wells located nearby sheep dip sites (Hadfield, 2022/2023). A study completed in 2003 in the Kaikoura Plains also found contamination of shallow groundwater was present at three locations where monitored wells were installed (Environment Canterbury & Pattle Delamore Partners Ltd, 2003).

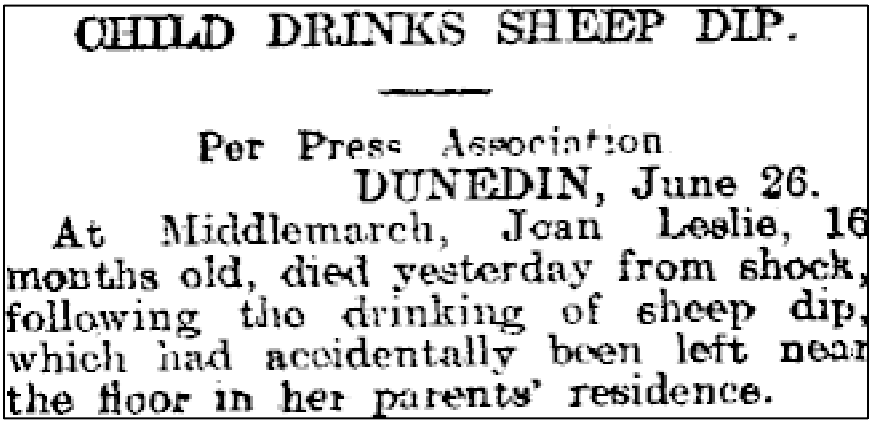
Duncan (1955) also recommended that a dip was emptied after use and refilled with water to prevent deterioration of the dip in between seasons. According to Duncan (1955) algal blooms were likely to occur in dips during the storage period and recommended dosing stagnant dips with 'bluestone', otherwise known as copper sulphate. Therefore, a likely source of additional heavy metal contamination if copper was not already used in the dipping process.

2.4 Impact of contaminants on human health and the environment

2.4.1 Human health

Contaminants in soil can enter the body via three main routes, ingestion, dermal absorption, and inhalation (Ministry for the Environment, 2011b). Ingestion is through the consumption of contaminated soil. This can be through a variety of methods, i.e., a child with pica eating soil, person eating or smoking after contact with contaminated soil without washing their hands or eating vegetables with soil particles attached. Dermal absorption is through direct skin contact with contaminants, for example direct contact with contaminated soils without correct PPE. Contaminants can also enter the body via the airway, this is usually through the inhalation of dust, therefore it is recommended that contaminated sites maintain good ground cover and the exposed soils are kept damp and respirators/masks are worn onsite.

The World Health Organisation (WHO) notes that inorganic arsenic can be highly toxic to humans (World Health Organisation, 2018). Acute effects of arsenic exposure have both short- and long-term effects, symptoms may present initially as gastrointestinal disruption (i.e., vomiting, and abdominal pain) and may escalate to dermatological issues (such as pigmentation changes and lesions) or lung/bladder cancer and other chronic illnesses such as diabetes and cardiovascular disease (World Health Organisation, 2018). Acute effects of sheep dip exposure have been recorded colloquially throughout the 1900's in New Zealand on many occasions through newspaper articles detailing the deaths of many adults and children (Figure 2.9).



CHILD DRINKS SHEEP DIP.

Per Press Association
DUNEDIN, June 26.

At Middlemarch, Joan Leslie, 16 months old, died yesterday from shock, following the drinking of sheep dip, which had accidentally been left near the floor in her parents' residence.

Figure 2.9 Article from New Zealand Times detailing the death of a child after consuming sheep dip fluid in 1923 (New Zealand Times, 1923)

Potential chronic effects of exposure to sheep dips were explored in research undertaken by Stephens et al. (1995) in the United Kingdom. Stephens et al., (1995) investigated the neuropsychological effects from long-term exposure to OCP's used on sheep farms and showed a myriad of long-term health concerns related to exposure of contaminants during historic sheep dipping activities. The study compared the cognitive ability and susceptibility to long term psychiatric disorders of 146 sheep farmers confirmed to have worked with OCP's in sheep dips to 143 quarry workers who were not involved with sheep dipping activities. Stephens et al. (1995) confirmed that the sheep farmers tended to present with lower levels of cognitive abilities and had a greater susceptibility to psychiatric disorders (although it is key to not dismiss other external factors on farmers. For example, more farmers vs quarry workers were found to be smokers, yet quarry workers were found to consume larger quantities of alcohol). The report concluded that those subjected to larger amounts of OCP's experienced subtle, yet quantifiable deterioration of their nervous systems. To date, in New Zealand, there has been no proven link between sheep dip exposure and long-term human health effects. However, in approximately 96% of sheep dips tested in the Waikato Region exceeded human health guidelines for contaminants in soil (Kim, 2003), therefore there is a likelihood of unrecorded event of potential human health effects.

2.4.2 Environmental impact

Ecological receptors are considered to be any terrestrial biota that has the potential to be adversely impacted by onsite contaminants (Cavanagh & Munir, 2019). Cavanagh and Munir (2019) define terrestrial biota as *"microbial processes, plants, soil invertebrates, wildlife and livestock" (*p. 7). Ecological soil guideline values (EcoSGV) operate in a similar way to the human health guidelines as they are based on a land use scenario framework. The EcoSGVs are based on the ecological worth of a site and generally tend to be more conservative when compared to human health guidelines due to the range and sensitivity of environmental receptors (Table 2.1).

Table 2.1 Table detailing the different land uses and level of protection provided by set EcoSGVs (Cavanagh and Munir, 2019)

Land use	NES land use	Additional land uses covered/Description	Receptors covered	Level of protection (%)[1]	
				Plants	Soil processes/ invertebrates
Commercial /Industrial	High density residential, Commercial / industrial outdoor worker	Road reserves. All commercial/industrial and high-density residential land use, including under paved areas. Highly artificial ecosystems but soils should still support the basic soil processes and be able to recover if land use changes.	Soil microbes, plants, invertebrates Soil and food ingestion, Trigger for off-site impacts	60 (65)	60 (65)
Residential and recreational areas	Rural residential/lifestyle block (25% produce consumption) Residential (10% produce consumption) Recreational areas	Modified ecosystems but for which there is still an expectation that important species and functions can be maintained.	Soil microbes, plants, invertebrates, wildlife	80 (85)	80 (85)
Agriculture, including pasture, horticulture and cropping	Production land[2]	All food production land. The protection of crop species is required to maintain the sustainability of agricultural land. Soil processes and soil invertebrates are highly important to ensure nutrient cycling to sustain crop species but tillage and use of pesticides mean it is not realistic to have the same level of protection as for plant species.	Soil microbes, plants, invertebrates, wildlife and livestock	95 (99)	80[3] (85)
Non-food production land	Production land	All non-food production land (e.g. production forestry) to which waste could be applied and which does not fall into other land use categories. Similar to agricultural land, although tillage and pesticide application is not expected to affect soil processes and soil invertebrates, enabling a higher level of protection for these organisms.	Soil microbes, plants, invertebrates, wildlife	95 (99)	95 (99)
Ecologically sensitive areas	NA	National Parks, designated ecologically sensitive areas. Near-pristine ecosystems that should remain in that condition.	Soil microbes, plants, invertebrates, wildlife	99	99

The EcoSGVs tend to be more conservative than human health guidelines depending on the land use, for example the Soil contaminant standards from *Users' guide: National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health* (NES SCS) provides an arsenic concentration threshold of 80 mg/kg for recreational land use (Ministry for the Environment, 2012), whereas the EcoSGVs recommended up to 60 mg/kg for the same land use.

2.5 Environmental factors affecting remnant contamination

Current NES SCS assumes that all contaminants in soil are completely (100%) bioavailable and the standards for remediation are developed around this expectation. There are a number of factors that influence both bioavailability, mobility, and contaminant retention in soils. As the main contaminants associated with historic sheep dip sites are arsenic (Section 2.5.1) and OCPs (Section 2.5.2), these have been explored in the following subsections.

2.5.1 Arsenic

Influences on arsenic mobility and uptake in New Zealand soils are largely based on the following soil factors:

- **Allophane/phosphate retention**: Soils containing allophane (Allophanic Soils) are found in New Zealand due to the accumulation of tephra from historic volcanic eruptions (Hewitt et al., 2021). Allophane is a clay mineral that has a strong ability to adsorb anions and therefore typically has a high level of phosphate retention (Hewitt et al., 2021). Arsenic becomes less bioavailable with soil aging; however the addition of phosphate increases the bioavailability of the arsenic (Bolan et al., 2013).
- **Soil pH:** Arsenic is highly soluble and therefore more mobile in neutral to alkaline conditions and is only moderately soluble in acidic conditions (Akter et al., 2005).
- **Organic matter:** Soils with high levels of organic matter tended to have higher level of arsenic bioavailability **(**Meunier et al., 2011).

2.5.2 Organochlorine pesticides

Although OCPs are considered persistent organic pollutants and are relatively stable with typically long half-lives of up to 12 years, they do slowly break down in soil over time (Tzanetou & Karasali, 2022). OCPs tend to remain in surface soils as they are typically hydrophobic and adhere to soil particles (Tzanetou & Karasali, 2022). It is considered that OCPs are likely to be more persistent in soil with small particle sizes, for example it would be expected that a higher OCP concentration would be found in a soil with a high clay content when compared to soil with a low clay content (Edwards, 1975). Another factor influencing OCP retention in soils is the amount of organic matter. Soils with greater amounts of organic matter tend to have greater adsorption and persistence of OCPs (Edwards, 1975). Soil with high concentrations of arsenic may increase the half-life of OCPs as both contaminants inhibit microbial activity which help the breakdown of OCPs (van Zwieten et al., 2003).

2.6 Historic contaminated land management guidelines and best practice

Prior to the development of the MfE CLMG No.1-5 and the NES, there were no established guidance in the investigation of sheep dip sites or soil contaminant standards for either the protection of human health or the environment. Health and Environmental Guidelines for Selected Timber Treatment Chemicals were published by Ministry for the Environment in collaboration with Ministry of Health in 1997 (Ministry for the Environment & Ministry of Health, 1997).

The 1997 Health and Environmental Guidelines for Selected Timber Treatment Chemicals were initially created to provide advice for the investigation and management of timber treatment sites and provided contaminant guidelines for both the protection of human health and livestock. These guidelines provided a contaminant standard for arsenic and copper, which are common contaminants associated with sheep dip sites. Due to this, the guidance used for timber treatment sites was applied to sheep dipping sites in the absence of any other best practice.

Although the Health and Environmental Guidelines for Selected Timber Treatment Chemicals (1997) was the only resource available at the time and provided guideline values for arsenic and copper, it did not provide guidance on sampling methodologies for sheep dips sites or guidance on guideline values for the protection of human health for OCP's and would not be considered fit for purpose for use on sheep dip sites.

2.7 Current guidance provided by Ministry for the Environment for the investigation of sheep dip sites

The Ministry for the Environment published the guidance: 'Identifying, Investigating and Managing Risks Associated with Former Sheep Dips: A guide for local authorities' (herein referred to as the sheep dip guidelines) in 2006 (Ministry for the Environment, 2006). These guidelines aimed to raise awareness of the potential health and environmental impacts of sheep dips and to guide regulators in how to approach sheep dips from a contaminated land perspective. The sheep dip guidelines were intended to provide guidance on:

- Locating sheep dips
- Evaluating potential risk of sites to both human health and the environment
- Creating an understanding of remediation and management options

The sheep dip guidelines provided a brief history of sheep dipping practices, chemicals used and provided resources such as guideline values, sampling guidance, questionnaires and other guidance that may help in an investigation of a sheep dip site. It is important to note that Tier One human health values in the sheep dip guidelines have since been superseded by the NES.

The sheep dip guidelines provided insight on chemical contaminants expected to be found based on year that the dip was active. The sheep dip guidelines are an integral part of this research as the contaminants outlined are the basis of the sampling methodology.

Table 2.2 Known chemicals used during sheep dipping over time (adapted from Ministry for the Environment, 2006)

Contaminants of Concern	Known years of use
Arsenic	1840 - 1980
Copper	1950-Present
DDT (OCP)	1945 - 1961
Lindane (OCP)	1947-1961
Dieldrin (OCP)	1955 - 1961
Alrin (OCP)	1955 - 1961
Year	1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990

It is clear that arsenic was used more consistently (Table 2.2) throughout the period of usage of most other contaminants. Based on this knowledge, this research uses arsenic as a common indicator contaminant for the presence of sheep dip chemicals. OCP's did not become commonplace until approximately 1945-1961 (Table 2.2).

The sheep dip guidelines indicate that soil sampling at depth should be completed where the highest concentrations of contaminants are found or if the dip area has been significantly disturbed. The sheep dip guidelines also encourage the identification of all potential receptors, for example ecological and offsite receptors alongside potential human health risks.

The sheep dip guidelines review multiple sampling methods and approaches including judgmental sampling (selecting specific sampling points based on site knowledge), systemic sampling using sniffer dogs to detect OCP residues and onsite sampling methodologies such as the use of a pXRF (although this technology was relatively new at the time the guidelines were published).

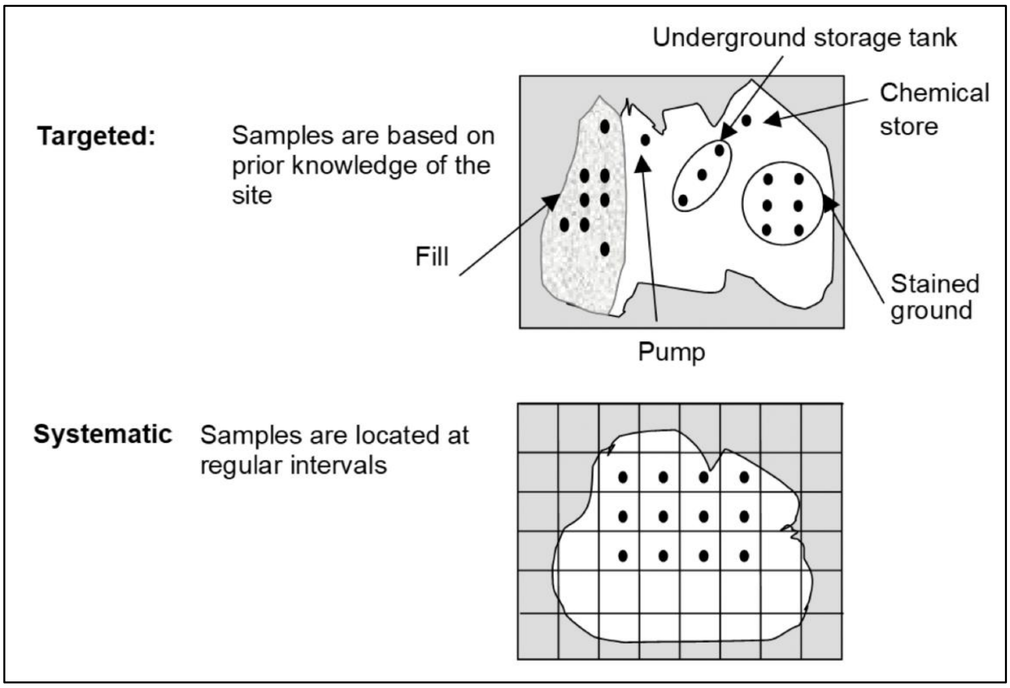


Figure 2.10 Main sampling methodologies as described in MfE CLMG No.5 (Ministry for the Environment, 2021b)

The guidelines consider that systemic sampling (Figure 2.10) is the most effective approach to sheep dip investigation. This sampling approach uses a grid-based sampling pattern and is used to delineate the full extent of potential contamination which reduces the risk of missing hotspots of contaminants. Although this approach was considered to produce the highest quality data, it typically carries a high financial cost and therefore is less feasible for typical contaminated land investigations. This work attempts to investigate whether predictable patterns might enable a less sample intensive, highly targeted alternative.

2.8 Regulatory management of historic sheep dip sites

Local government plays a large part in how sheep dip sites are investigated and managed. Regional, unitary and district councils fulfil different roles dependant on two different legislations.

Regional and unitary councils operate under the RMA (Resource Management Act 1991) and supporting framework of regional and unitary plans. These councils may grant resource consents for earthworks and discharges on potentially contaminated sheep dip sites based on standard of reporting and effects of proposed works. The main consideration of these councils is potential adverse effects to both human health, the environment, and if there is the potential for discharge of contaminants offsite.

District councils typically have their own district plans with rules relating to the use, subdivision, and development of contaminated land, but the main legislation which overrides these controls is the NES (Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011). The NES has controls which create 'trigger' scenarios for the investigation and potential remediation of potentially contaminated site. Unitary authorities also have control over the implementation of the NES and is required to fulfil both function of a district and regional Council authority.

The NES (Ministry for the Environment, 2012) is implemented through the use of Ministry for the Environments Hazardous Activities and Industries List (HAIL) (Ministry for the Environment, 2011d). The HAIL list has 53 different activities and industries that have the potential to cause contamination and is split into nine different categories:

Table 2.3 Summary of the main categories from MfE HAIL (Ministry for the Environment, 2011d).

A	Chemical manufacture, application, and bulk storage
	A8. Livestock dip or spray race operations
B	Electrical and electronic works, power generation and transmission
C	Explosives and ordinances production, storage, and use
D	Metal extraction, refining and reprocessing, storage, and use
E	Mineral extraction, refining and reprocessing, storage, and use
F	Vehicle refuelling, service, and repair
G	Cemeteries and waste recycling, treatment, and disposal
H	Any land that has been subject to the migration of hazardous substances from adjacent land in sufficient quantity that it could be a risk to human health or the environment
I	Any other land that has been subject to the intentional or accidental release of a hazardous substance in sufficient quantity that it could be a risk to human health or the environment

Sheep dipping activities fall under category A (A8. Livestock dip or spray race operations) and are a trigger for the requirement of NES consent if certain changes were to occur on a site (Ministry for the Environment, 2012). The main triggers for the requirement of an NES consent (Ministry for the Environment, 2012) for a sheep dip site are as follows:

- Onsite soil disturbance (i.e., earthworks associated with building or a subdivision development)
- Subdivision of a site (i.e., major subdivisions or even the separation of an area from a larger farm)
- Change of land use (i.e., rural residential property becoming a residential lot)

These activities can be controlled under the NES dependant on whether the activity can be completed as a permitted activity or if it requires a consent as a controlled activity or discretionary activity. A number of set measures are used to establish what consent a site requires under the NES (Appendix A).

Both regional plan requirements and NES consenting requirements are considered in the planning of potential use of historic sheep dipping sites. Regional Council's main function in relation to contaminated land under the RMA is *"the investigation of land for the purposes of identifying and monitoring contaminated land"* (Resource Management Act 1991). Regional councils in New Zealand typically fulfil this function through the creation a register for sites noted as having had a HAIL activity occur onsite. For example, Waikato Regional Council holds the Land Use Information Register which contains a list of sites that have current or historic onsite activities that appear on the HAIL list. This information is used to inform district councils and any interested parties of information relating to contaminated land in the Waikato region (Waikato Regional Council, 2019). It should be noted that district councils also often hold their own information regarding these sites and the two data sources are not integrated.

2.9 Current contaminated land management guidelines

Ministry for the Environment's NES (2012) sets accepted levels of contamination based on human health risk. These levels are set according to the level of exposure or direct contact that people would have with contaminated soil under five specific land use types. Below (Table 2.4) is adapted from the NES (Ministry for the Environment, 2012) and provides detail for 'acceptable' levels of contaminants commonly found at sheep dips:

Table 2.4 Soil contaminant standards for contaminants typically associated with historic sheep dipping activities (Ministry for the Environment, 2012)

Land use	Arsenic (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	DDT (mg/kg)	Dieldrin (mg/kg)
Rural residential / lifestyle block (Assumes that up to 25% of lot could be used for growing produce)	17	>10,000	160	45	1.1
Residential (Assumes that up to 10% of the lot could be used to grow produce for consumption)	20	>10,000	210	70	2.6
High-density residential (Assumes that there is limited potential soil contact onsite and that no produce is grown onsite for consumption)	45	>10,000	500	240	45
Parks/recreational spaces (Used for green spaces where children may be frequently accessing the site)	80	>10,000	880	400	70
Commercial/industrial sites (assumes that there may be exposed soil onsite that workers may have limited contact with soil and also allows for workers onsite that may not be fully paved)	70	>10,000	3,300	1,000	160

The soil contaminant standards outlined in the NES (Table 2.4) are derived from a risk assessment based on the potential intake rate of soil which is calculated using the equation shown below (Ministry for the Environment, 2011b):

$$soil\ guideline\ value = \frac{acceptable\ intake \times body\ weight \times averaging\ time}{contact\ rate \times exposure\ frequency\ \times exposure\ duration}$$

The equation above considers factors that may impact a receptors tolerance to a contaminant of concern such as weight, amount of exposure, frequency of exposure and generally accepted amount of contaminant that can be safely consumed. This may mean that a person living in an apartment building with no soil exposed onsite will have a much higher recommended soil guideline value compared with a lifestyle block where the occupants grow majority of their vegetables and spend a lot of time outdoors in contact with soil.

In terms of mobility of contaminants, OCP's such as Aldrin, DDT or Dieldrin appear to be only moderately mobile in soils and are unlikely to move far in a soil profile (Food and Agriculture Organization of the United Nations, 2000). OCP's also generally degrade over time but typically have a long half-life and soil conditions and co-contaminants are also a major factor (Food and Agriculture Organization of the United Nations, 2000; Van Zwieten et al., 2003). For example, DDT is relatively stable in composition and is not particularly affected by microbes and will remain for long periods of time in New Zealand soils (e.g. half-life of up to 10 years) as conditions are not favourable for rapid degradation (Boul, 1995).

2.10 Research needs

Chapter 2 highlights the importance of a thorough understanding of the history of a sheep dip site, type of dip and dipping practices used in order to effectively identify the risks a site might pose.

There appears to be information gaps in the current sheep dip guidelines regarding the use of mobile dipping units and dusting machines. It is not apparent how prevalent these dipping methodologies were and how they can be identified. It is also unclear which dipping products were commonly used in these dip types. The risk of contamination is unclear due to the transient nature of mobile dipping units. With regards to dusting machines the risk of significant soil contamination has yet to be quantified.

At the time of printing, no New Zealand studies were identified relating to the long-term health and ecological effects associated with sheep dip related contamination. Due to the prevalence of sheep dip sites in New Zealand and the potential contamination associated with them, it is considered that these sites potentially pose a risk to human health and the environment as discussed in sections 2.5.1 and 2.5.2. Further research is required to establish potential long term, chronic impacts of sheep dip related contaminant exposure.

This research focuses on understanding the current weakness and limitations in both the sheep dip guidelines and MFE CLMGs. This aims to enable further support in identification of historic sheep dip sites, higher quality reporting and support for landowners and local authorities.

Chapter 3

Methodology

3.1 Desktop study

3.1.1 Information gathering

In order to establish the current state of contaminated land reporting on sheep dips in New Zealand, Preliminary Site Investigations (PSIs) and Detailed Site Investigations (DSIs) were requested from twelve different regional and district councils across New Zealand. At the time of request, only six of the twelve approached both responded and held record of sheep dip investigations being completed within their jurisdictions. The six councils that were able to provide detailed site investigations for sheep dips are as follows:

- Bay of Plenty Regional Council (5 investigations)
- Environment Canterbury (49 investigations)
- Environment Southland (4 investigations)
- Hamilton City Council (3 investigations)
- Northland Regional Council (1 investigation)
- Waikato Regional Council (5 investigations)

Other resources that may help in the identification of potential contamination patterns were also retrieved and reviewed, for example historic agricultural bulletins (Duncan, 1955) and Ministry for the Environment sheep dip guidelines (Ministry for the Environment, 2006). This was to understand dipping practices and also to create an understanding of current best practice for investigation of sheep dip sites.

3.1.2 Data analysis

The reports were individually reviewed, and the following main information was collated in an excel spreadsheet:

- Location and relevant local authority
- Whether the report was completed in accordance with MfE CLMG No.1
- Dip type (communal dips were noted as their own dip type for ease of analysis)
- If sampling was undertaken and what methodology was used
- If contamination was found, what the main contaminant of concern was and the highest found concentration of that contaminant
- Year that the dip was first used (if known)

This data was then analysed to find potentially significant information or patterns that could help inform weaknesses in current contaminated land management reporting.

3.2 Field method

3.2.1 Public survey and study site resourcing

In order to find sheep dip sites for this study, a flyer (Appendix E: Sheep Dip Study Flyer) and letter (Appendix F: Letter Regarding Sheep Dip Study) were created alongside a survey (Appendix D: Public Survey Results) which were delivered in rural areas with known historic sheep dip sites. The poster was placed on local farmer Facebook groups (such as Waikato Farmers, North Waikato Young Farmers and NZ Sheep and Beef Farmers), community groups in towns that had high number of sheep farms (such as Ngaroma Community Noticeboard and Te Kuiti, Otorohanga, Pirongia Buy Sell and Swap Group). This survey was posted in social media groups with approximately 20,000 members combined.

The survey included the following general questions:

- If the respondent was aware of a sheep dip being on their property, if yes, then:
    - Did the respondent wish to remain anonymous
    - How long had they owned the property
    - What was the site land use
    - If the dip was still in situ or if it had been removed
    - What type of dip was used onsite
    - What chemicals were used in the dip
    - How long was the dip used for
    - Was the dip used solely by the dip owner or was it open for community use
    - What features was the dip located near (i.e., woolshed, watercourse, road and etc.)
    - Where were the dipping chemicals used stored
    - Where was the used dipping fluid disposed

The results of this survey are summarised in section 4.1 and were also used to help obtain a study site. Through this survey, a landowner provided details of a sheep dip and allowed for sampling of their site with a spray unit, this site and the sampling methodology used is described further in section 3.2.2.

3.2.2 Site description and Sampling

To ensure the anonymity of the site owner and location of dip, the sheep dip location is herein referred to as 'The Site'. The Site consists of a woolshed and stockyards constructed sometime between 1950 and 1966 (according to available historic aerial imagery). The site owner provided an undated image of the spray shower unit (Figure 3.1).

Figure 3.1 Spray shower unit historically located onsite

Based on the shape/design evident in Figure 3.1, the unit was likely a Stewart reciprocating sheep shower (Duncan, 1955). As the shower unit was constructed earlier, sometime between 1950 and 1966, there was a likelihood that both arsenicals and organochlorine pesticides were used in the dipping practices, therefore soils were tested for both heavy metals and organochlorine pesticides.

The site was visited on the 27th of January 2022. The weather conditions at the time of sampling were fine with some clouds. At the time of the visit, the spray unit had been removed (Figure 3.2) but the woolshed and surrounding stockyards were still in place. The site owner noted that the sump was still in-situ, but had been covered by soil in the centre of the pen (Figure 3.2)

Figure 3.2 Picture across historic sheep unit area from the woolshed. The red outline indicates the historic spray unit location, the yellow outline indicates the drainage pads, and the blue star indicates the location of the spray unit sump as indicated by the site owner.

3.2.3 Site investigation

Site investigation for historic sheep dip contamination was undertaken through a combination of in-situ analysis of heavy metals using a portable X-ray fluorescence analyser, specifically the Olympus Delta pXRF (Figure 3.3) and an analysis of collected soil samples (heavy metals and organochlorine pesticides). Organochlorine pesticide samples were only taken in locations where the highest heavy metal concentrations were found to confirm presence/absence, as it was assumed that if the dip had been used consistently throughout its life, the same area would be affected by both contaminant types.

Figure 3.3 Olympus Delta pXRF in use on the site

3.2.4 Sampling design

pXRF samples were initially taken directly adjacent to the dip to establish the potential sampling pattern. It was assumed that due to dipping processes, the highest levels of contaminants would be found in these areas, from that point a sampling pattern could be created. Due to the lack of arsenic contamination present onsite, the explorative sampling methodology was continued laterally outward. Soil samples were collected from where the highest levels of arsenic contamination were found nearby the spray unit area. Samples labelled as at depth were taken at an approximate maximum depth of 0.15m.

3.2.5 Field QA/QC

Sampling equipment, such as the auger and trowel were washed with water and Decon-90 in between samples. Gloves were used and changed in between the collection of each sample. The soil samples collected for lab analysis were kept in a chilly bin filled with ice and were stored on cold hold (approximately 4°C) until they were transported to Hills Laboratories for analysis.

The pXRF was calibrated both prior to sampling and during using the supplied stainless-steel plate, SiO_2 blank and soil standard (2711a).

3.2.6 Field data analysis

Results were retrieved from the pXRF and Hills Laboratories receipts. These results were entered into ArcGIS Pro by creating shapefiles and then producing a heat map through the use of symbology. This analysis was then used to create an indicative sampling document for the landowner (Appendix B: Indicative Site Sampling Report) and to also analyse any potential patterns of contamination onsite.

Chapter 4

Results

4.1 4.14.24.3Survey results

Only twelve responses to the survey were received and of those twelve responses, ten had knowledge of a sheep dip existing on their property. The results from the respondents with known dips have been summarised in this section, although any potentially identifying information has been removed from the discussion as seven out of the ten with known dips, specifically requested anonymity.

Of the ten responses with known dips, nine reported that the main farmland use was still sheep farming. Only one response noted the change in land use to dairy farming. The types of dips varied significantly and were reported as follows:

- One reported only using a plunge dip onsite
- Three reported only using a pot dip onsite
- Two reported only using portable units onsite
- Two reported only using spray units onsite
- One reported having a plunge dip, pot dip and a spray unit onsite
- One reported having a plunge dip and spray unit onsite whilst also using a portable unit

As a follow up question to the types of dips used onsite, the respondents were also asked if the dip was still on the property. Three of the ten responses noted that the dip had been removed, while the remaining seven noted that the dip was still onsite. One respondent specifically noted that the site had a 'modern' mobile unit onsite that was still in use and stored in a shed when not in use that does not require chemical disposal due to its technology. The dip was noted as the Electrodip that has "Magic Eye" technology, which is marketed as a low volume, high pressure dip created to reduce time spent dipping and chemical wastage (Electrodip, 2018).

In terms of dip location, all ten respondents that noted the farm had, or currently has, a dip said that they were located near a woolshed. Six out of the ten respondents noted that the dip was located near stockyards and two said the dip was located near a stream.

Only seven out of ten respondents noted how long they had been involved in the operation of the property, one of which said they were only leasing the property. Of the remaining six responses, four had owned the property between 3-5 years (although one noted that although they had owned the farm for a relatively short time period, it had been a family farm since 1941) and two had owned the site for between 30-35 years.

Half of the respondents (five) were unsure what chemicals had been used in the dipping process, however three mentioned the use of arsenic, two mentioned the use of DDT specifically, one mentioned unknown OCPs and one noted the use of diflubenzuron and cyromazine (diflubenzuron and cyromazine were specifically used in the Electrodip with the "Magic Eye" mechanism, this dip was noted to still be in use). Two respondents said that dipping chemicals were stored in the woolshed, four noted the use of a shed specifically for chemical storage (although one respondent did note that they were unsure of historic dipping products storage as the chemical storage has been used for modern dipping products), one respondent noted storage in an animal health cupboard and two respondents were unsure where dipping fluids may have been stored.

Although most respondents noted different disposal methods for used dipping fluid, four noted disposing of the used fluid into a nearby paddock or down a nearby hill. One respondent noted that the used fluid was spread across the yard, one said that the used fluid was poured over the pad to 'filter out' (it is assumed that this means drainage pads). One respondent noted that the fluid was drained into a sump, and another said the fluid was 'washed down to soak away'. The site that reported using the Electrodip recorded that no disposal of fluid was needed.

4.2 Review of existing detailed site investigations

67 DSIs were reviewed and the reporting showed that current sheep dip related investigations are largely not completed in accordance with MfE CLMG's and the sheep dip guidelines.

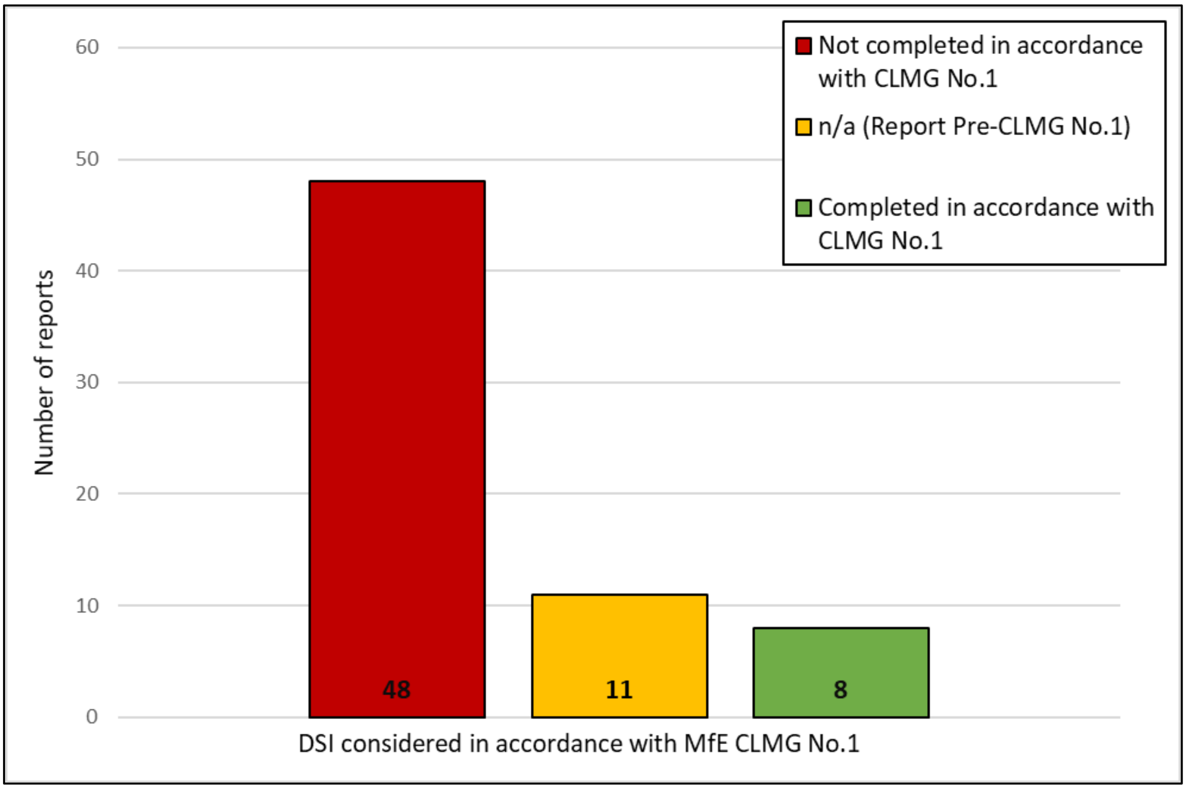


Figure 4.1 Graph showing the number of reports completed in accordance with MfE CLMG No.1

Approximately 48 of the total 67 (72%) DSIs received that were reviewed against MfE CLMG No.1 were found to not be completed in accordance with guidelines (Figure 4.1). The values noted as n/a (Figure 4.1) were taken from investigations that were completed prior to the release of MfE CLMG No.1 and therefore cannot be compared with the guidance. The DSIs that fall into this category account for 16% of reports reviewed. Of the DSIs reviewed, approximately 12% were considered to be completed in accordance with MfE CLMG No.1 (Figure 4.1).

Some key reporting deficiencies that contributed to the majority of non-complying reports were:

- **Sampling design:** Many reports only included surface soil samples and did not provide depth samples. Potential vertical migration of contaminants was often dismissed or ignored.
- **Missing sampling results:** 16% of investigations reviewed did not include sampling results (if sampled).
- **Site history:** Investigations that did not meet MfE CLMG No.1 often did not provide a thorough site history.

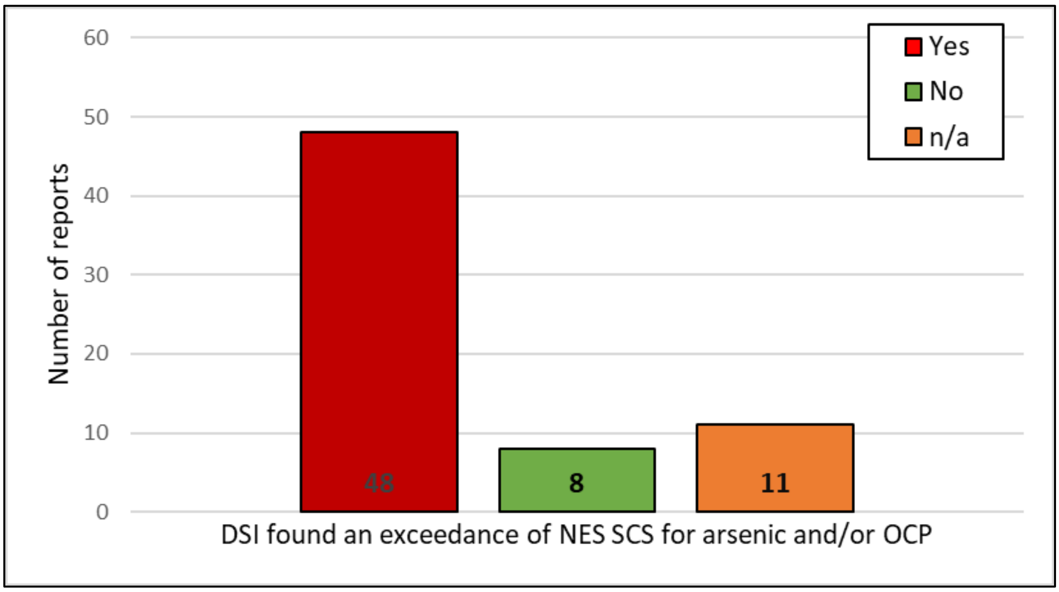


Figure 4.2 **Graph showing the number of detailed site investigations which found exceedances of NES SCS for the intended land use**

Approximately 72% of reviewed investigations found contamination associated with sheep dip activities that exceeded the NES SCS for the particular land use of the site (Figure 4.2). Of the remaining investigations approximately 16% did not include sampling results and approximately 12% did not find contamination that exceeded NES SCS for the particular land use of the site.

Approximately 69% of investigations that found contamination onsite noted arsenic exceeding NES SCS for the specified land use. Approximately 19% of investigations found levels of dieldrin that exceeded NES SCS for the specified land use and 6% of sites found lead at levels that exceeded NES SCS for the specified land use.

There is potential for more significant, but undetected, contamination on these sites due to the large number of investigations not completed in accordance with CLMGs. This may be due to inadequate sampling onsite or lack of identification of areas and contaminants of concern. Contamination was only noted as significant if it exceeded the NES SCS for the proposed land use, therefore some sites may exceed standards for other land use scenarios or protection of environmental receptors but were not considered contaminated for the particular land use.

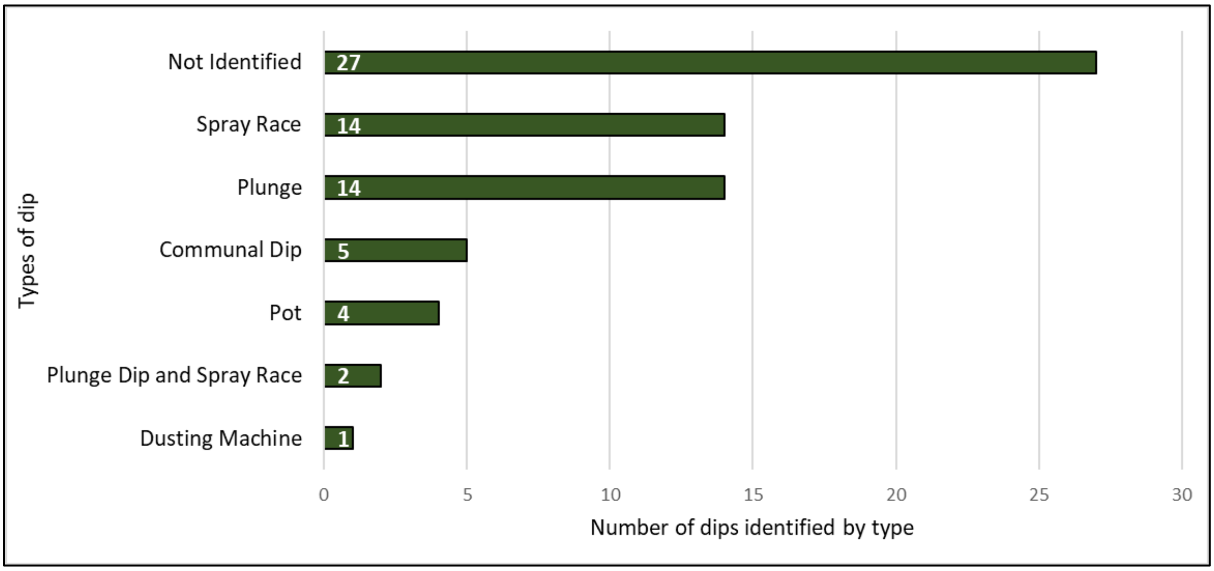


Figure 4.3 Graph showing the number of each dip type identified by DSIs

Of the investigations reviewed, 40% did not identify the type of dip (Figure 4.3), 70% of investigations did not attempt to identify an approximate time of use of the dips; which is important as dip type and time of use impacts potential contaminants of concern.

Out of the 14 spray units identified in the reviewed investigations, eight (57%) were found to have exceedances of NES SCS. Contaminants found at the investigated spray races were arsenic and dieldrin. Arsenic found at spray races ranged from 21 mg/kg to 430 mg/kg and dieldrin ranged from 5.4 mg/kg to 12.7 mg/kg.

There were approximately 18 plunge or pot dips identified in the reviewed investigations, of those 18, 11 (61%) were found to have contamination onsite that exceeded NES SCS for the specified land use. Arsenic and dieldrin were found to be the main contaminants of concern. Arsenic ranged from 51 mg/kg to 3900 mg/kg and dieldrin ranged from 1.79 mg/kg to 5.1 mg/kg.

Communal dip investigations were included in the review and four sites were identified. Contamination was identified at all four sites that exceeded the NES SCS for the specified land use. Lead was identified on one site (220 mg/kg) but was found adjacent to a building onsite and therefore is likely to be associated with historic use of lead paint. The main identified contaminant of concern was found to be arsenic. Arsenic found at communal dip sites ranged from 189 mg/kg up to 2680 mg/kg.

A site was identified where a dusting machine was used historically. The landowner noted dieldrin was the active ingredient used in the dusting machine. Dieldrin was found to exceed NES SCS for the specified land use and was found up to 6.1 mg/kg.

Foot rot baths have historically used arsenicals (Ministry for the Environment, 2006b) alongside other agents such as copper sulphate (also known as bluestone). Three investigations were reviewed that specifically noted the presence of a footbath in the area, only two of these sites were sampled and both reports noted arsenic exceeded NES SCS adjacent to the footbaths. One report noted arsenic up to 5,800 mg/kg at the end of the footbath and the other reported arsenic up to 66mg/kg adjacent to the foot bath. The potential for foot rot baths on sheep dip sites should be considered as a potential complication when investigating sheep dip sites.

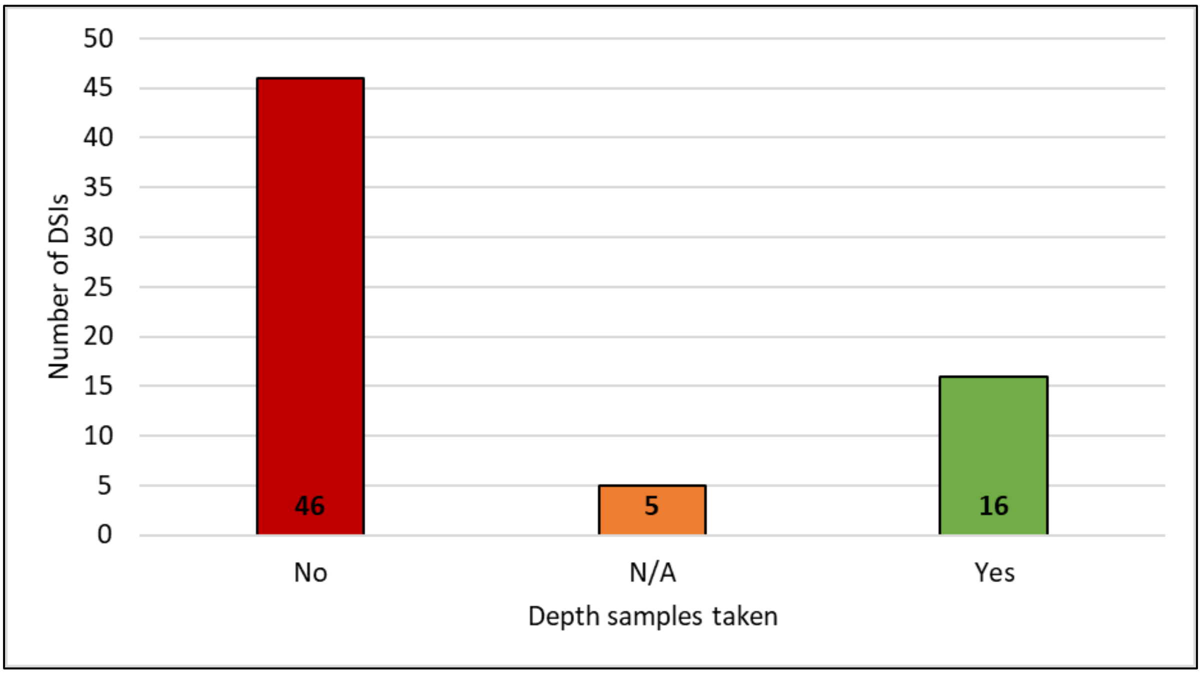


Figure 4.4 **Graph showing the number of DSIs that included soil samples at depths greater than 300mm**

Out of the 67 DSIs provided, 46 (68.5%) did not provide any depth sampling beyond 300 mm depth (Figure 4.4). Of the remaining DSIs, 16 (24.5%) did provide sampling at depth and the remaining 5 DSIs (75%) were completed as either part of interim reporting/revisions to existing reports and it was unclear if depth sampling had been completed (Figure 4.4).

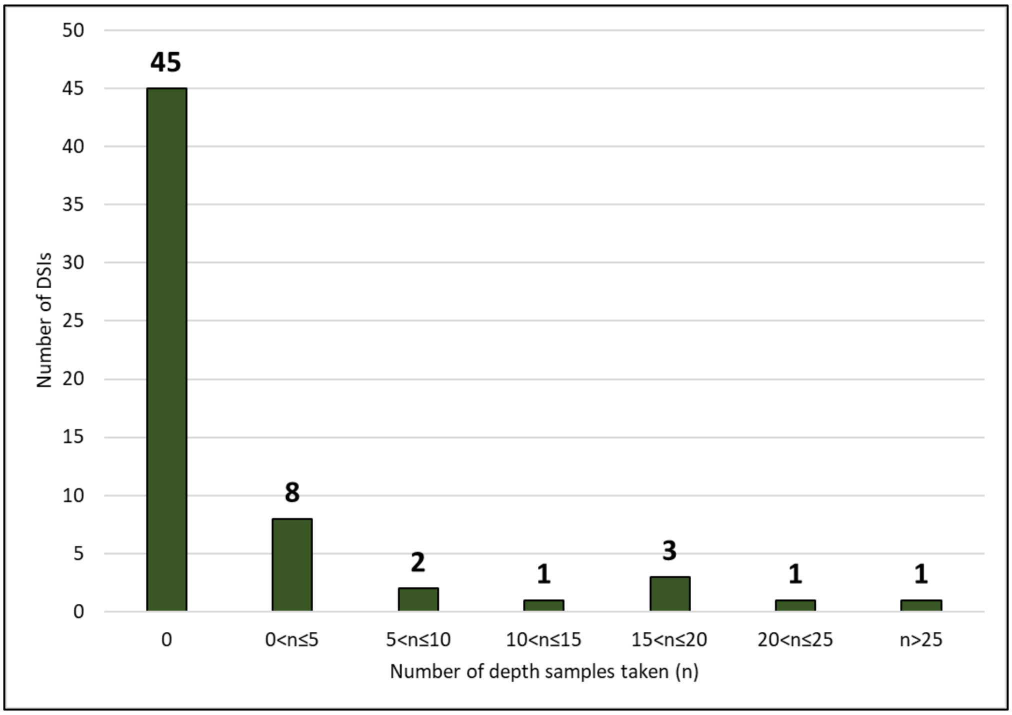


Figure 4.5 Number of depth samples taken by DSIs that analysed depth samples

The majority of DSIs that did take depth samples took less than five samples from the site (Figure 4.5), six DSIs took between five and twenty depth samples (Figure 4.5). There were two outliers, one DSI reported taking twenty-three samples at depth and another reported taking twenty-six depth samples (Figure 4.5).

4.3 Results from study site

The site (Figure 4.6) consisted of a woolshed, stockyards, and the concrete remnants of the historic spray unit.

Figure 4.6 Soil sample locations at the site as detailed in Table 4.1, red rectangle indicates the location of the historic spray unit. Sample labelled with LS are samples submitted for lab analysis.

Soil onsite was found to not be of natural origin, soils were largely comprised of imported fill, sands and gravel overlain by hardstand.

Elevated arsenic (up to 38.7 mg/kg) and dieldrin (up to 2.6 mg/kg) was found in samples taken adjacent to where the spray unit was historically located. Heavy metal concentrations, specifically arsenic, decrease with depth where samples were taken (depth samples ranged from 4.1 mg/kg to 20.1 mg/kg of arsenic). Samples taken directly adjacent to the concrete base where the spray unit was once located had dieldrin at concentrations more than two times the NES SCS value for rural residential land use (1.1 mg/kg). However, a sample taken approximately two metres away from the concrete base from the former unit showed dieldrin within NES SCS rural residential land use at 0.47 mg/kg.

The results (Table 4.1) indicate that the site has been impacted by historic sheep dipping activities. Samples 4 -24 were analysed using the pXRF and samples denoted with LS or lab were analysed through Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in a lab setting. Dieldrin and arsenic being the main contaminants of concern correlate with the estimated time of use of the spray unit (sometime after 1950, but prior to 1961). The levels of arsenic and dieldrin found onsite are considerably lower than those levels noted in the review of other spray unit investigations in section 4.1. Arsenic appears to have a higher level of variability between spray unit site, but the study site had lower levels of arsenic than expected, as arsenic was found at 38.7 mg/kg at the highest point.

Table 4.1 **pXRF and lab results from soil samples and fence post taken from the site as part of the onsite methodology, bold numbers indicated concentrations in excess of NES SCS for rural residential land use.**

Sample	Cr (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	As (mg/kg)	Pb (mg/kg)	Dieldrin (mg/kg)
4	12	2245	909	**25.9**	26.2	-
5	53	1079	104	**38.7**	41.9	-
6	0	10	64	10.4	12.2	-
7	28	8.8	363	6.7	13.6	-
8	18	32.8	316	11.4	12	-
9	19	40	496	**24.1**	23.5	-
10 (from depth at location 6 – 0.15m)	38	12.1	44.4	4.1	12.1	-
11	37	43	675	16.9	28.1	-
12	42	25.7	133	**27.1**	19.3	-
13	30	36	338	13.1	19.9	-
14	35	55	886	24.5	33.2	-
16	31	10.3	107.3	6.3	10.8	-
20 (from depth at location LS2 – 0.15m)	41	51	74.7	8.3	15.6	-
21 (from depth at location LS1 – 0.15m)	37	44	906	**20.1**	23	-
23	30	17.8	87.9	8.6	14.6	-
24	32	20	35.4	3.8	9.2	-
Lab analysed - (LS1)	17	105	2400	**38**	46	**2.6**
Lab analysed - (LS2)	9	75	82	10	19	0.47
NES SCS - Rural Residential/Lifestyle Block (25% produce) (Ministry for the Environment, 2012)	290	>10,000	-	17	160	1.1
Unpublished Waikato Regional Council ambient background soil trace element concentrations – 95th percentile (Taylor, M., 2024)	96	25	57	9.5	25	-
Proposed guideline values for protection of ecological receptors (Agricultural land) (Cavanagh & Munir, 2019)	300	220	190	20	530	-

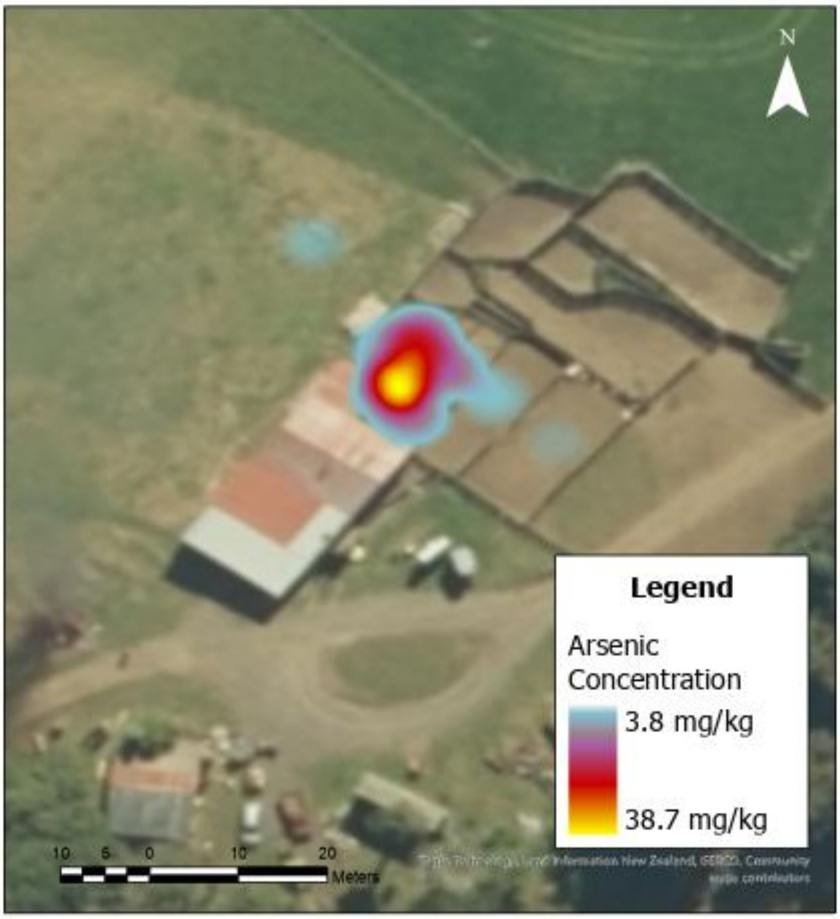


Figure 4.7 **Arsenic heat map of sampling area (not including timber fence post sample). Red shading indicates higher levels of arsenic, blue indicates lower levels of arsenic.**

In general, arsenic was found at lower concentrations further away from the dip, whereas higher concentrations of arsenic were only found within the immediate vicinity of the spray unit (Figure 4.7). Detailed information is available in (Appendix B: Indicative Site Sampling Report).

Sample 4 and sample 5 were taken directly adjacent to the spray unit on both the south -eastern and north-western side, where it was assumed the fence surrounding the unit would have been located when looking at the historic image site owner (Figure 3.1). Arsenic was elevated above the NES SCS for rural residential land use (17 mg/kg) at both locations (25.9 mg/kg – sample 4, and 38.7 mg/kg - sample 5), while both copper and zinc were found to be elevated above background soil concentrations (Taylor, M., 2024).

Figure 4.8 Rusted drum and container in the vicinity of sample 9 (indicated by the red point)

Samples 9 and 11 were taken adjacent to the drainage pad of the historic spray unit. Sample 9 was taken on the north-western edge (the assumed direction of drainage) of the drainage pad in the vicinity of a rusted drum and container. It was unclear what the use of the drum and container was as there was no clear labelling, and both were in a deteriorated condition (Figure 4.8), however, arsenic was found in this location in excess of NES SCS for rural residential land use (17 mg/kg). Sample 11 was taken from the edge of the drainage pad, arsenic was found to be elevated above background levels but was found to be below the NES SCS for rural residential land use (17 mg/kg).

Figure 4.9 Hole in drainage pad where sample 12 was analysed (indicated by red circle)

Holes (likely historic fence post locations) were visible in the concrete drainage pad during the sampling visit (Figure 4.9), therefore sample 12 was collected and analysed using the pXRF from one of these holes (the reason for the presence of the holes is unclear as they were reasonably symmetrical and uniform in size). Arsenic was found to exceed NES SCS for arsenic at this location (17 mg/kg).

Sample 21 and LS1 were taken from approximately the same location, which was nearby the exit of the drainage pad and adjacent to the exit of the spray unit, sample 21 was taken at depth (0.15m). Arsenic was found to exceed NES SCS for rural residential land use in both samples (20.1 mg/kg for sample 21, 38 mg/kg for LS1). It appears that at this location, arsenic decreases with depth as it was found at 38 mg/kg in surface soils (LS1) and 20.1 mg/kg at depth (Sample 21 – 0.15m). Dieldrin was also found in LS1 (2.6 mg/kg) in this location to be more than two times the NES SCS for rural residential land use (1.1 mg/kg), indicating historic use of dieldrin based dipping chemicals.

LS2 was taken adjacent to the spray unit on the northern edge, dieldrin was found to be elevated in this location (0.47 mg/kg) but was within NES SCS for rural residential land use (1.1 mg/kg). This sample was taken as it was in the direction of assumed drainage as the site slopes off significantly on the northern edge of the stockyards (Figure 4.6).

Chapter 5
Discussion

5.1 Public sheep dip survey

The results of the survey conducted are not considered robust due to low numbers of respondents; and instead formed a preliminary approach to gaining understanding of the public's knowledge and understanding of sheep dipping activities that may have occurred on their properties. As twelve responses were received from a potential catchment of 20,000 participants and only ten of those respondents reported sheep dips onsite, this survey cannot be relied on to create a full understanding of dip use, but some preliminary conclusions can be made with the awareness of the data limitations.

Just under half of respondents noted that they had owned the property with a known sheep dip for five years or less and a further half of the respondents were unsure of what chemicals may have been used in historic dipping processes. It can therefore be assumed that knowledge of historic dipping activities is being lost over time and with changing land ownership. The level of knowledge regarding historic dipping practices may continue to decrease over time, especially as disused dips are removed as three responses noted.

All ten respondents that noted a sheep dip on their property confirmed that the dip was located nearby a woolshed and six respondents confirmed that the dip was located near stockyards; this correlates with the sheep dip guidelines advice for identifying sheep dip sites based off structural evidence (Ministry for the Environment, 2006). Of note was that two respondents commented that the dip was located nearby a stream and also reported that the dip was a plunge dip, this is in alignment with guidance in the sheep dip guidelines that streams, and water courses may have been convenient discharge points for a sheep dip (Ministry for the Environment, 2006).

A final key point is the general reluctance to participate in research regarding sheep dips. Although the survey was shared across social media and via letter drops, there was an apparent reluctance to disclose information and the majority of those that did respond to the survey specifically requested that they remain anonymous. In total, there were just over 20,000 participants across all the Facebook groups where the survey information was posted, therefore, a reasonably large catchment of sheep farm owners may have viewed the request, yet only twelve responses were received and only one site owner allowed their farm to be sampled. Comments on Facebook posts also indicated a strong negative response to identification and disclosure of sheep dip sites and a strong public perception that the disclosure of sheep dip sites would devalue property, create significant financial burden, and create regulatory or enforcement issues with local councils.

5.2 Impacts of current guidelines on the standard of reporting

Due to the substantial number of DSIs that did not meet MfE CLMG No.1 (48 out of 67 or 72%) it is considered that the current sheep dip guidelines and MfE CLMGs are not effective in driving high quality and thorough investigations of sheep dip sites.

5.2.1 Sheep dip guidelines

Currently the sheep dip guidelines only provide limited guidance regarding the identification of historic sheep dip sites from a desktop survey. Desktop surveys often consist of a review of historic aerial imagery for sites, which is where historic HAIL activities are most often identified. Historic aerial imagery is used by local government to add sites to their contaminated land registers and also by practitioners' conducting initial research on a site for investigations. The main indicators of a potential sheep dip noted in the sheep dip guidelines as stockyards, woolsheds, and a water source (Ministry for the Environment, 2006). There, however, appears to be significant variation in the layout of each sheep dip site, with some being visible and easily picked up in aerial imagery to sites that it may not initially be apparent that a sheep dip was once present (Figure 5.1).

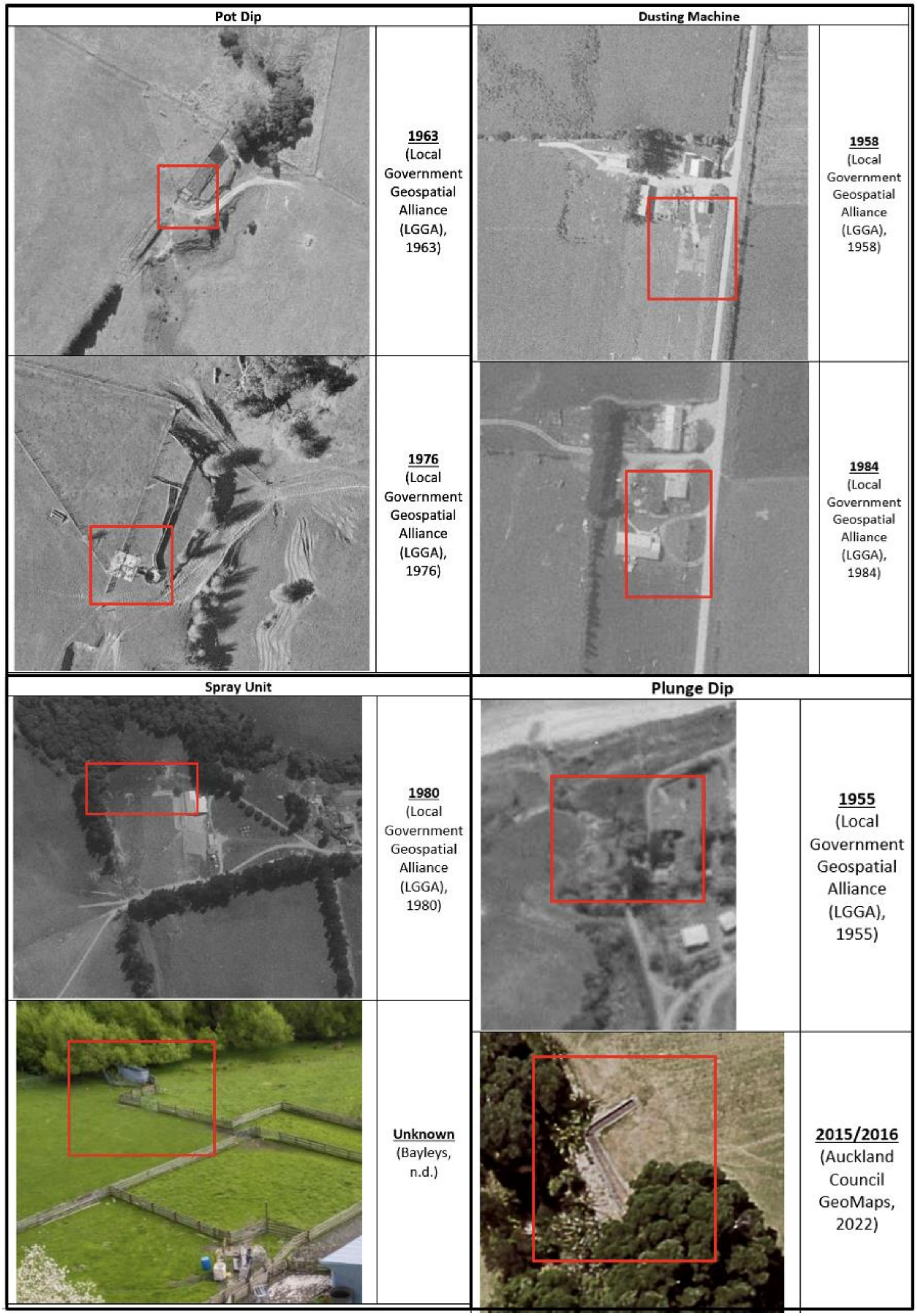


Figure 5.1 **Images of known sheep dip locations with features that significantly differ from those indicated as identifying features in the sheep dip guidelines. Sheep dips are identified by the red box. LGGA images are sourced from http://retrolens.nz and licensed by LINZ CC-BY 3.0**

The current sheep dip guidelines do not provide examples of historic aerial imagery for confirmed dip locations, only 'on the ground imagery' for a limited number of dips. It is possible that pictorial guidance would be more useful to end users for the identification of sheep dip sites.

There is also limited information currently available in the sheep dip guidelines regarding the use and prevalence of both mobile dipping and dusting units. The dipping methodology, and commonly used chemicals are not discussed and therefore require further guidance.

The sheep dip guidelines are highly dependent on local knowledge within the community and a property owner's knowledge and willingness to come forward regarding these sites (Ministry for the Environment, 2006). The sheep dip guidelines provide a checklist for landowners to assess potential risk and initial management steps in relation to sheep dip sites. This relies on a site owner having a thorough knowledge of a dip (what type of dip and age of the dip) its use (what products were used, where product was stored and disposed) and the infrastructure relating to the dip (i.e., discharge pipes, sumps, and drainage pads) (Ministry for the Environment, 2006). It is also possible that this guidance document is too long and technical to appeal and feel usable to a non-technical audience.

It is considered that as time progresses, the knowledge of dip sites will progressively be lost. The survey discussed in section 4.1 identified that knowledge of dips is limited and is being lost over time and as time progresses, site owners will not be able to use this checklist due to limited site knowledge or may not know about a dip at all due to removal of disused dips that are not disclosed. Site owners may also be unaware of multiple dips being located on larger farm sites and may only be able to identify the main dipping sites and not secondary dipping locations located on a property.

Another limitation of the site owner's checklist are the areas that require assessment may not cover the entirety of the dipping operation. The current areas of assessment are only associated with dipping using liquid product and may miss areas of contamination associated with the storage and disposal of dipping product, its packaging and contamination associated with dusting.

The final limitation with the site owner's checklist is the management options presented to site owners. The management options are limited and presented as options '*to be determined in conjunction with council or specialist advice'* (Ministry for the Environment, 2006, p. 55). This statement does not consider the cost, time and involvement required for the decision of site management and a local authority may not be prepared to provide advice due to liability or may not have the specialist knowledge available to advise on management processes. A management option proposed is the use of planting and potentially creating a plantation forest in areas of sheep dip associated contamination. Although this would restrict access of both animals and humans to the site for a number of years, the planting and harvesting process could potentially create a pathway for exposure to contaminants as trees are often planted by hand (Eastland Wood Council, 2018) leading to direct contact with potentially contaminated soils. When harvesting occurs, there may be further risk of offsite transport of contaminants due to heavy machinery potentially tracking contaminated soil offsite and areas that are cleared after harvesting may be at risk of erosion, leading to a potential further spread of contaminants.

5.2.2 Impact of Ministry for the Environment Contaminated Land Management Guidelines on standards of reporting

Given 72% of DSIs were not completed in accordance with MfE CLMG No.1 the guidelines appear inadequate in encouraging thorough and detailed reporting on sheep dip sites. A site history is crucial to evaluate potential patterns of contamination on sheep dip sites and contaminants of concern.

The main information gap in the reviewed DSIs is that they did not provide an adequate site history, which is critical in establishing a sampling plan to fit a sheep dip site. Although current MfE CLMG No.1 provides checklist requirements regarding site history, most reports do not appear to cover these points, for example 40% of DSIs did not attempt to identify the type of dip used onsite or that 70% of the DSIs did not provide an approximate duration of dipping. This indicates important data gaps and that the checklists provided do not encourage adequate research into site history. There may be other factors influencing this, however, for example new site owners, second generation farmers or sites where the original dip may have been destroyed may severely limit information about the historic dipping practices. Some sites may also have limited historic imagery available and the ability to identify and date a dip may be difficult.

Due to the lack of an adequate site history in the reviewed DSIs, limited discussion regarding the rationale behind sampling design was provided. As there was often limited knowledge about environmental factors such as soil type, the potential for vertical migration of contaminants was often ignored. At least 69% of DSIs reviewed did not provided any depth sampling or assessment of potential vertical migration of contaminants. Due to the lack of depth sampling, it is considered that the sites investigated were not fully characterised and therefore pose a risk to future remediation, management plans and human health.

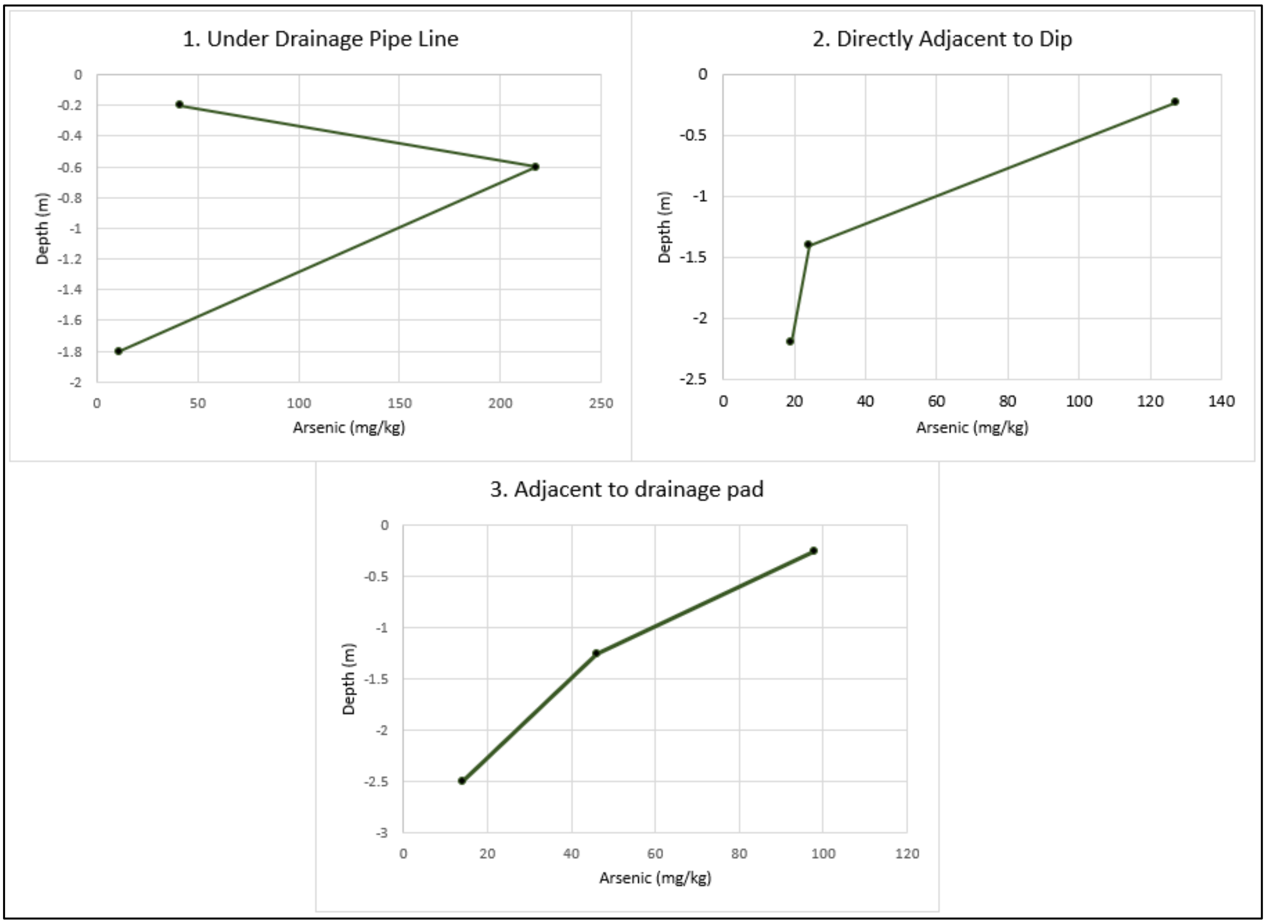


Figure 5.2 **Graphs showing the changes in arsenic concentrations (mg/kg) at depth. The three graphs represent three sampling locations from a pot dip DSI reviewed as part of the methodology.**

Of the DSIs reviewed, one completed for a pot dip in 2001 had the most comprehensive number of samples taken at depth (26 in total). Three sample locations near the pot dip and under the drainage pipe (not at the discharge point) were found to have arsenic at depth at concentrations higher than the current day NES SCS for residential land use of 20 mg/kg (Figure 5.2).

Site 1 (Figure 5.2) soil arsenic concentrations were analysed at three depths underneath a discharge pipe: in the topsoil (0.2 m below the ground surface), then 0.6 m into the subsoil, and 1.8 m into the subsoil. At this location, arsenic (41 mg/kg) in the topsoil (0.2 m) was found to be twice the NES SCS for residential land use (20 mg/kg) but was then found to be approximately 11 times (218 mg/kg) the NES SCS for residential land use (20 mg/kg) at 0.6 m depth (Figure 5.2) and within NES SCS for residential land use (20 mg/kg) at 1.8 m depth (11 mg/kg). An iron drainage pipe was identified at approximately 0.6m depth and may be responsible for the spike in arsenic. This shows that arsenic was found higher at depth than in the surface soils and without sufficient depth sampling or site knowledge (dip layout, pattern of use, drainage points/pipes, etc.), there may have been a hazard to those undertaking earthworks onsite and potentially living onsite depending on the intended future land use.

Soil samples from Site 2 (Figure 5.2) were taken directly adjacent to the pot dip, including surface soils (0.23 m BGL), 1.4 m and 2.2 m depth. Arsenic in the topsoil (127 mg/kg) was approximately six times the NES SCS for residential land use (20 mg/kg). Arsenic did decrease with depth, at 1.4m depth arsenic concentrations only marginally exceeded the NES SCS for residential land use at 24 mg/kg and were within NES SCS for residential land use at 2.2m depth at 19 mg/kg.

The soil samples from Site 3 (Figure 5.2), which were sampled from beside a drainage pad, followed the same general pattern as site 2. In surface soils (0.25 m BGL) arsenic was found to be approximately five times (98 mg/kg) the NES SCS for residential land use (20 mg/kg), at 1.25 m depth arsenic (46 mg/kg) was approximately two times the NES SCS for residential land use (20 mg/kg) and at 2.5 m depth, arsenic was within the NES SCS for residential land use (20 mg/kg).

It is unclear if the reviewed reports were deemed sufficient by the respective local authorities, how they were used or if they were challenged. However, the poor compliance of reporting with the current MfE CLMGs suggests that the guidance does not provide adequate encouragement to ensure that reporting provided to local authorities is of sufficient standard.

5.3 Impacts of local government processes on the standard of reporting

The high number of DSIs that were not considered to be completed in accordance with MfE CLMG No.1 (48 out of 67 or 72%) would indicate that the governing district or regional authorities *may* have been accepting inadequately completed reports. There may be many influencing factors that contribute to substandard reporting including potential weaknesses in guidance for contaminated land reporting (outlined in section 4.1), and potential limitations and deficiencies in guidance for the investigation and management of potentially contaminated sites (outlined in section 4.2).

An important consideration is both the financial and time cost involved in reviewing and providing feedback incurred by local government and their staff. Often local government staff operate with low budgets and high workloads and are not necessarily specialists in contaminated land. These employees are expected to cover large areas of knowledge, from planning, specific legislation/rules applying to each property, district and regional plans and do not typically have the benefit of familiarising themselves with the complexities of MfE CLMGs and the everchanging contaminated land landscape.

5.4 Potential deterrents to disclosure and investigation of sheep dip sites

Sheep dips were government mandated, and little to no choice was given to sheep farmers at the time, however, there is currently little to no financial resource or technical support available to owners of sheep dip sites. The sheep dip guidelines (Ministry for the Environment, 2006b) estimated the costs of fully investigating a sheep dip site in 2006 at up to $15,000 without remediation, so the true cost in 2022 is likely to be significantly higher. In terms of financial assistance, there are few options for site owners to support investigation to assess the risk and potential remediation/management requirements. One of the few avenues for potential financial compensation is through the Ministry for the Environments Contaminated Sites Remediation Fund (CSRF), although this provides its own roadblocks. The CSRF currently only accepts applications completed by regional or unitary councils. Application to the CSRF is a time consuming and costly process, does not fund the entirety of a project, and generally only ‘orphan’ sites that have no potential for funding through other avenues and that pose significant and imminent risk to both human health and the environment such as larger industrial sites or landfills are funded (Ministry for the Environment, 2021c).

Due to this reliance on regional and unitary authorities, sheep dip sites are unable to compete for council resources when compared with sites that pose an imminent risk to human health or the environment. Due to this lack of financial support, site owners may be less likely to come forward and voluntarily disclose sheep dip sites or provide information to inform investigations for the fear of potentially contaminated status being placed on their land that they do not have the financial ability to remediate.

A potential option to help farmers with site investigation and remediation costs is to remove the requirement for a regional or unitary authority in the CSRF application process. Through removing this required intermediatory, it may be more accessible for site owners to apply for this fund. Although access to this fund would be a positive step forward in assisting landowners, there are many limiting factors to consider.

The main limiting factor may be that owners of sheep dip sites will still be competing with much larger orphan sites for funding. This may mean that the cost and time involved in applying for this fund is essentially rendered redundant. At the time of this study, the CSRF has $2.63 million (Ministry for the Environment, 2021c) available annually for funding of both investigation and remediation of sites. Although $2.63 million is available, the CSRF is not required to use the total amount if it does not deem that the sites of interest require it and typically only partially funds applications that are successful, which still leaves a potential significant financial burden on the landowner.

Another limitation with the fund going forward is if sites that have received financial assistance through the CRSF are sold, a portion of those profits may be shared with all parties that helped with funding the site remediation, therefore impacting the governance and financial returns of the site going forward.

A final limiting factor is the publicity surrounding the use of the CSRF fund. If an applicant is successful in receiving funding, details regarding the site are typically announced in a press release from the Minister for the Environment. This publicity may bring unwanted attention to a site and may be off-putting to some due to public perception of risk associated with contaminated land. Site owners may fear that their properties are being devalued or marked in a sense for the foreseeable future. Due to the potential limiting factors of this fund as it currently stands, it is unlikely to encourage site owners to disclose sheep dip sites or ensure proper investigation of sites.

Another option for financial assistance for landowners may be through the creation of sheep dip site funds that are held by regional or unitary authorities. Application processes may be less burdensome than the current CSRF processes due to the regional and unitary authorities’ knowledge of their own communities, regions and the areas being split when compared with the national approach currently used. As most, if not all, regional and unitary authorities already have a register for potentially contaminated sites, information regarding investigated or remediated sites could be stored within this database, therefore the information is still publicly and freely available, but is not released to the public through national media statements.

There are, however, limitations with this approach, for example where the funding for this resource comes from. Regional and unitary authorities are largely funded by rate payers, so could create a negative public perception, or could be considered unfair by communities to help fund these sites. The regional and unitary authorities that would be managing this fund often struggle with staff and resourcing, so may not be feasible to delegate the fund to them.

A middle ground approach may be that a small portion of the CSRF budget is split off from the overarching larger fund. This portion of the fund could be opened to applications to the public with supervision of the application being covered by a Suitably Qualified and Experienced Practitioner (SQEP) and could be in the form of a direct contribution towards a portion of the cost or a simple set value grant. This would allow for much simpler access to the CSRF fund as it would not require regional/unitary endorsement and would therefore allow greater flexibility for applicants. This approach would, however, require a significant change to the current CSRF application process. As members of the public would be applying for this fund, the application process would need to be streamlined and updated to be more accessible to those without a technical contaminated land background. Also, the current ranking and 'judging' process undertaken by CSRF panel members may have to be adjusted to accommodate potentially smaller, less complicated sites. Other limitations include the deterrent of the use of the CSRF due to the public disclosure of sites if accepted by the CSRF. The CSRF may take portions of the profits if a site is ever sold in the future, this portion of the fund could be released to the media as statistics (i.e., general area and costs) and the removal of the financial penalty could encourage more member of the public to apply. The overarching objective of the CSRF is to "help regional councils / unitary authorities facilitate the investigation, remedial planning, and remediation of sites that pose a risk to human health and the environment. It is designed to encourage willing parties to investigate and remediate contaminated land." (Ministry for the Environment, 2011a) Thus, the removal of the complexities of the application process (as mentioned above), protection of privacy of site details or landowners, and removal of financial penalties would help the CSRF achieve this goal.

Fonterra and Beef + Lamb New Zealand were approached for this research to establish what (if any) support may be available for farmers with sheep dips located on their farms. No response was provided by Beef + Lamb New Zealand at the time of printing. According to the response provided by Fonterra (H. Acland, personal communication, June 29th, 2022), the company currently requires the disclosure of sheep dip sites and any other potentially contaminating activities on farms, and how the site owner intends on managing these sites prior to onboarding. Each year, an assessor completes an assessment of the farms and if any hazards are established (for example a sheep dip that had not been noted), the site owner will be provided with required actions to remedy the issue. Any potential risks to water supplies are also checked on a three yearly basis, so a dip might also be picked up during this assessment. Fonterra requires access to sheep dip sites to be minimised, but the responsibility falls onto site owners, although extensive rules and regulations are in place to minimise potential for milk contamination, Fonterra does not appear to provide any further support regarding actioning management of these sites (H. Acland, personal communication, June 29th, 2022).

As indicated by the lack of resources available to farmers, limited survey respondents and only one site owner coming forward regarding their sheep dip site, a major deterrent to site owners may be the disadvantages associated with the disclosure of a sheep dip site as a potentially contaminated site, ongoing financial and emotional distress. According to research by Goffin (2014) at the farmer level, two main stressors for farmers are related to financial concerns/stability and the effects of government regulation on their farm. Therefore, it's considered that the disclosure of a sheep dip site to local government and the financial impact going forward has the potential to have a detrimental effect on the mental health of site owners/farmers and therefore deter site owners from disclosing these sites.

5.5 Recommendations

Further research is required for certain sheep dipping methodologies and the potential contamination associated with the methods as was outlined in section 2.10. This further research also needs to establish the potential long term, chronic impacts of sheep dip related contaminant exposure. However, the following recommendations may encourage site owners to come forward and proactively disclose, investigate, and establish management of sheep dip sites, whilst also providing further support to the local authorities overseeing compliance with regulatory requirements regarding contaminated land:

- A review of the current CSRF application and funding processes to enable landowners with the guidance of a SQEP to apply for funding for the investigation and remediation of sites. Alongside this, the removal of identifying details from public notification for accepted sites within a certain financial threshold would encourage those with contaminated sites to apply for the fund.
- The integration of a proactive approach to identification and notification of sheep dip sites by local authorities is encouraged. Identification and notification of sites before plans to change land use may help to reduce pressure on landowners as they will be aware of these sites and the implications and therefore can plan accordingly.
- Further to the point above, a change in the method of communication of identified sheep dip sites may be beneficial. The ability to include potential routes to financial support and potentially even mental health resources (for example, working with Farmstrong or the Mental health Foundation on wording for notification letters and to include number for mental health support) may help to reduce both short- and long-term negative impacts on site owners.
- With the loss of knowledge of sheep dip sites over time and the majority of sheep dip sites yet to been identified, it is important that knowledge regarding sheep dip sites and the potential risks is provided to next generation farmers. An ongoing effort of education and notification of site owners of sheep dip sites would be beneficial to the reduction of risks from these sites going forward.
- Further to the point above, education may help to lessen the negativity associated with soil contamination. Spreading awareness of the prevalence of sheep dip sites and increasing public awareness of remediation and management options and long-term benefits and risks of these approaches may help to lessen negative reactions to historic sheep dip sites.
- Further information, images from sites and guidance for the identification of sheep dip sites should be created that is accessible to both local authorities and the general public. This would allow for more efficient and accurate identification of sheep dip sites, would reduce sites

identified in error and also would help to reduce the number of sites potentially being missed during the identification process.

- Local authorities could be provided with further resources in terms of staff with technical contaminated land knowledge or through sharing knowledge with other authorities. This could be established through forums or working groups which would allow for the sharing of technical knowledge and a collaborative approach to sheep dip sites.
- The inclusion of information regarding historic sheep dip sites specifically targeted to those without technical knowledge would benefit site owners and local communities. This would allow for risk reduction through education.

5.6 Research limitations

There are possible limitations in this study that are important to consider in the context of this research, they are as follows:

- A limitation for this study was the inability to find study sites for sampling. There was an apparent reluctance for site owners to engage in this study which may be due to many reasons. For example, concerns over lack of knowledge of historic dipping activities, site anonymity concerns/fear of disclosure, perception of soil contamination, potential risks, liability, and costs associated with the discovery of potential soil contamination were deterrents to participation.
- Due to the inability to find willing study sites to sample for this study, another limitation would be that only one site could be sampled. Therefore, there was little ability to compare study sites and their results between each other, and the reviewed reports.
- The lack of public interaction with this study also meant that there was a very limited number of responses to the survey. Due to this, the survey cannot be considered as comprehensive but has been used to identify potential issues regarding disclosure of dip sites and information relating to dipping practices.
- Due to the aforementioned limitations, the approach to this study was adjusted part of the way through. The initial approach to this study was to sample multiple sites to establish potential patterns of contamination. Due to the issues with finding study sites, the research was pivoted to review current standard of reporting and guidelines to identify potential weaknesses and limitations.
- Another limitation is the relatively low number of DSIs received from councils. Only 67 DSIs were received across the twelve Councils contacted. Although this data has been used to indicate trends in standards of reporting, it is not considered comprehensive in terms of potential contamination at historic sheep dip sites.
- Although the known sheep dip types have been summarised in chapter 2, it is considered that it is likely that the use of each dip and its construction would differ from site to site and cannot be considered comprehensive.
- A final limitation is that the site visited and described in the study has limited sampling due to the sampling methodology used to approach the site and therefore is not considered to be completed in accordance with MfE CLMG No.1. The use of the pXRF onsite was limited due to the lack of significant arsenic concentration associated with the historic spray unit and therefore potential patterns of contamination were largely unable to be identified.

Chapter 6
Conclusions

The main aim of this study was to create an understanding of potential weaknesses and limitations in current MfE CLMGs and the sheep dip guidelines. This was completed through a review of DSIs and a public survey regarding sheep dip sites. This work found that there was significant non-compliance with MfE CLMGs in the DSIs reviewed, significant public negativity in terms of contaminated land and a loss of knowledge regarding historic dipping practices over time.

The main deficiencies in reporting included a lack of a sufficient site history and sampling that did not fully characterize the potential contamination around the historic sheep dip sites. The exact reasoning for the non-compliance with MfE CLMGs is unclear but could be considered that the prohibitive costs of investigation/sampling, limited resources available to local authorities and landowners impacted the expected compliance and standard of reporting.

The second aim was to review existing sheep dip guidelines to identify any potential weaknesses and information gaps. It was considered that the sheep dip guidelines do not currently provide sufficient information to help landowners and local authorities accurately identify historic sheep dip sites and types of dips. The sheep dip guidelines also do not provide up-to-date and accessible information to help support landowners in decision making. Another restricting factor is that the current sheep dip guidelines rely heavily on the knowledge of the site owner or the local community regarding use and location of historic sheep dips.

The third aim was to test the existing CLMGs and sheep dip guidelines in informing effective sampling methodology for a sheep dip site. Due to limitations of the onsite methodology using the pXRF, a full site investigation using the recommended sampling designs was not feasible.

The fourth aim was to establish what deterrents and barriers may exist that might prevent the disclosure of sheep dip sites. Both the survey responses and interactions with the survey posts on social media indicate a strong negative reaction from the public to topics of contaminated land and local government. Due to a lack of accessible resources for education, financial support for investigation and potential remediation, there was significant stigma surrounding historic sheep dip sites. This stigma has the potential to impact future investigations and limit public willingness to disclose sheep dip sites.

Overall, the first issue regarding historic sheep dip sites was the significant stigma surrounding the potentially contaminated site and the lack of resources available to landowners. There is an apparent lack of accessible information for landowners in current guidance and the inability to access any financial support. This is considered to have stunted both already completed investigations and the willingness of others to come forward or disclose information. Finally, it is considered that there is a lack of resources available to those working in local government identifying sheep dip sites and enforcing compliance of investigations with MfE CLMGs and the sheep dip guidelines.

In order to provide further support to local authorities reviewing sheep dip investigations, opportunities to share technical knowledge could be established through working groups or forums, and further resources (such as sheep dip identification guides) and support could be provided to those already working in these roles. A proactive approach to the identification and notification of sheep dip sites is encouraged in order to reduce long term risk and potential complications. During the suggested proactive approach to notifying landowner of sheep dip sites, it would be beneficial to include mental health resources to reduce any short- and/or long-term negative impacts on the mental health of site owners.

It is also recommended that further resources are provided to owners of historic sheep dip sites. A review of the current CSRF application process is recommended to encourage landowners to apply for funding. Changes could include enabling landowners to apply for the fund with the support of a SQEP; the removal of the requirement of public notification of accepted sites; and removal long-term financial penalties. This has the potential to encourage site owners to come forward and disclose sheep dip sites on their own volition.

Finally, it is considered that education and the inclusion of accessible information for landowners would help to reduce stigma and educate on risks surrounding sheep dip sites. This should include the education of next generation farmers on what to look for and the potential risks involved when accessing sheep dip sites and the best next steps in terms of remediation and management of these sites.

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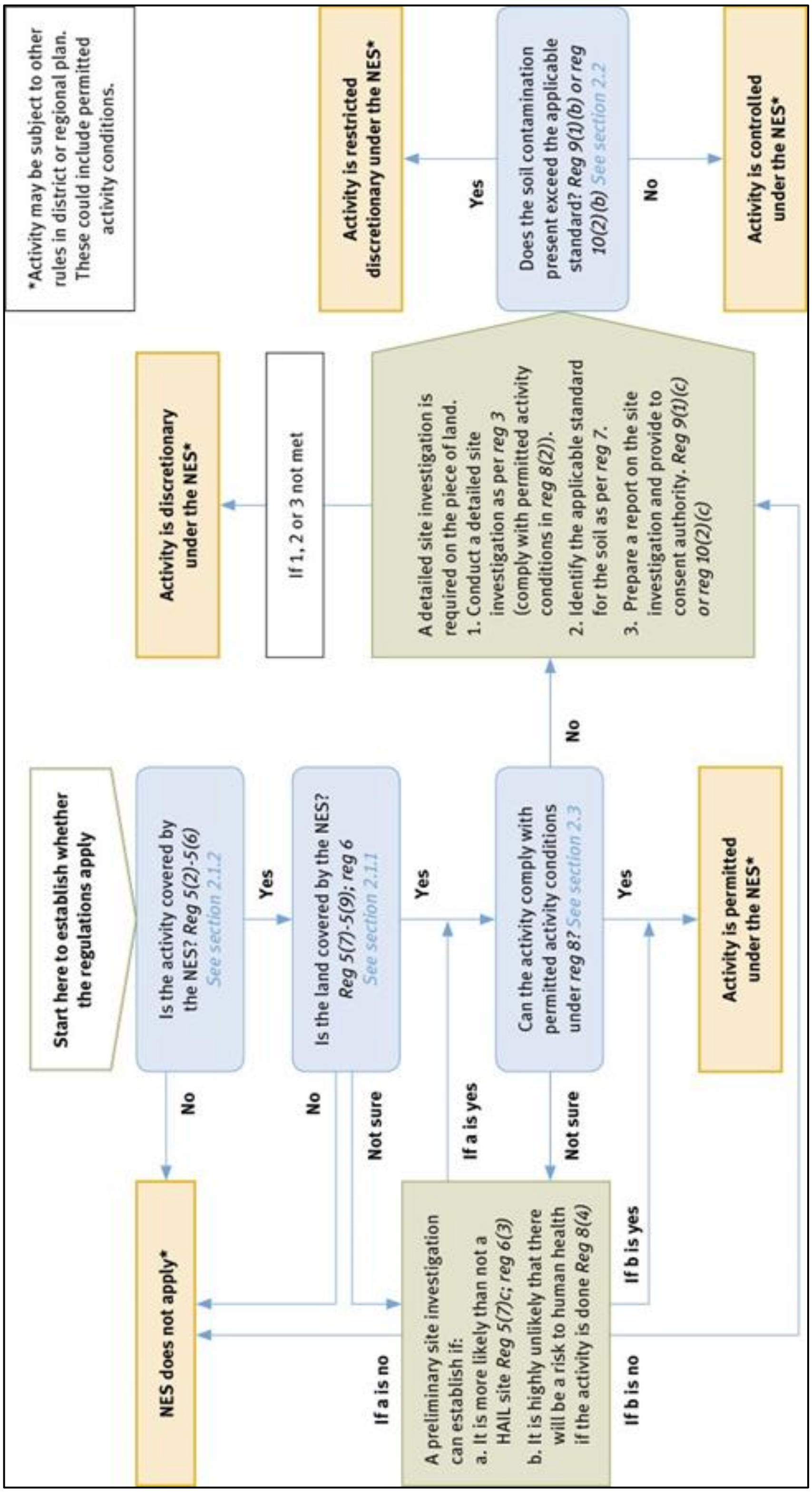
Appendices

Appendix A: Flowchart for Establishing the Potential Consenting Requirement for a HAIL Site Under the NES (Ministry for the Environment, 2012)



Appendix B: Indicative Site Sampling Report

Contents

Introduction

Sheep dips and spray units were historically used on sheep farms for the treatment of parasites in sheep's wool, specifically scab (Ministry for the Environment, 2006). Sheep were pushed through baths or were sprayed with chemicals; they were then moved into drainage pens to allow the dipping fluid to drain back into the dip or a sump. Dips and spray units often used arsenicals or organochlorine pesticides.

Address	[redacted]
Legal description	[redacted]
VRN	[redacted]

The site was visited on 27th of January 2022 as a spray unit was historically located onsite. The weather conditions at the time of sampling were fine with some clouds. At the time of the visit, the spray unit had been removed, but the woolshed and surrounding stockyards were still in place. The site owner noted that the sump, although not visible, was still in-situ but had been covered by soil in the centre of the middle pen (approximate location is denoted by the blue star below in image 1). The spray unit had been removed, but the concrete base (red area in image 1 below) and drainage pad (yellow area in image 1 below) remained in place.

Image 1: Picture of sheep yards showing location of unit, drainage pens and sump

2

The spray unit onsite was constructed sometime after 1951 but prior to 1966 although exact dates are unclear. The site owner provided information on chemicals that were known to have been used onsite (see appendix B). The potential construction date indicates that there is a likelihood that arsenicals, copper and organochlorine pesticides may have been used (Ministry for the Environment, 2006).

Methodology

Sampling was undertaken based on the potential chemical used onsite, this was done through a combination of in-situ analysis of heavy metals using a portable X-ray fluorescence analyser (DELTA Environmental Handheld XRF Analyzer) and also lab analysis of two collected samples (heavy metals and organochlorine pesticides).

Organochlorine pesticide samples (OCP's) were only taken in locations where the highest heavy metal concentrations were found to confirm/deny their presence. It was assumed that the unit was used in the same manner regardless of the chemicals used in the unit, therefore the OCP concentrations would most likely match arsenic concentrations. The concrete base to the spray unit and drainage pad were still in place, these areas were unable to be sampled.

Sampling equipment, such as the trowel, were washed with water and Decon-90 in between samples. Gloves were changed in between the collection of each lab sample. Samples were stored in a chilly bin on ice in the field and then were refrigerated until they were taken to Hills Laboratories for analysis.

The pXRF was calibrated prior to and during sampling using provided stainless steel calibration plates, soil standard (2711a) and SiO_2 standard. Plants and any large debris were removed from the soil surface, a film was placed on the soil surface to protect the pXRF (as seen in image 2 below) and the sample was analysed. Samples highlighted in the results table below indicate that they have been taken at depth (10-15 cm below ground level). Heavy metals included in the discussion are common contaminants found in areas of sheep dipping, chromium was also included as it may help indicate sources of arsenic (i.e., elevated copper, chromium and arsenic may indicate that the soil has been affected by treated timber).

Image 2: pXRF in use onsite

Results and discussion

Sample Name	Cr (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	As (mg/kg)	Pb (mg/kg)	Dieldrin (mg/kg)
Sample 4	12	2245	909	**25.9**	26.2	-
Sample 5	53	1079	104	**38.7**	41.9	-
Sample 6	0	10	64	10.4	12.2	-
Sample 7	28	8.8	363	6.7	13.6	-
Sample 8	18	32.8	316	11.4	12	-
Sample 9	19	40	496	**24.1**	23.5	-
DEPTH: Sample 10	38	12.1	44.4	4.1	12.1	-
Sample 11	37	43	675	16.9	28.1	-
Sample 12	42	25.7	133	**27.1**	19.3	-
Sample 13	30	36	338	13.1	19.9	-
Sample 14	35	55	886	24.5	33.2	-
Fence Post	5082	1310	89	3121	11.8	
Sample 16	31	10.3	107.3	6.3	10.8	-
DEPTH: Sample 20	41	51	74.7	8.3	15.6	-
DEPTH: Sample 21	37	44	906	**20.1**	23	-
Sample 23	30	17.8	87.9	8.6	14.6	-
Sample 24	32	20	35.4	3.8	9.2	-
Lab Sample - Sheep 1 (LS1)	17	105	2400	**38**	46	**2.6**
Lab Sample - Sheep 2 (LS2)	9	75	82	10	19	0.47
NES SCS - Rural Residential/Lifestyle Block (25% produce) (Ministry for the Environment, 2012)	290	>10,000	-	17	160	1.1
Waikato Region background soil concentrations (Waikato Regional Council, 2019)	30	25	53	6.8	20	-
Proposed guideline values for protection of ecological receptors (Agricultural land) (Cavanagh & Munir, 2019)	300	220	190	20	530	-

Table 1: pXRF and lab results

Results in **bold** represent values exceeding applicable guideline values for Rural Residential/Lifestyle block land use.

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Table 1 shows that more than half of the soil samples exceed expected naturally occurring background concentrations of arsenic, however most samples were within soil guidelines for the protection of human health. Further discussion regarding elevated samples is provided below.

Description of samples returning elevated results:

Heavy metals

Sample 4 was located directly adjacent to the spray unit area on the south-eastern side, next to where it is assumed the fence line for the spray unit would have been. Arsenic was elevated above recommended soil guideline for the protection of human health. Copper and zinc were also elevated above expected background soil concentrations in these areas but were not found to exceed recommended soil guidelines for the protection of human health.

Sample 5 was taken directly adjacent to the spray unit area on north-western side near to the fence line. Arsenic was found to be more than two times the recommended soil guideline for the protection of human health. Copper and zinc were also elevated above expected background soil concentrations in these areas but were not found to exceed recommended soil guidelines for the protection of human health.

Sample 9 was taken directly adjacent north-western edge of the drainage pad. Arsenic was found to exceed the recommended soil guideline for the protection of human health. It should be noted that a rusted barrel was present in this location, it is unclear what the barrel was used for as it was in a deteriorated condition.

Sample 11 was taken at the assumed exit to the drainage pads. Arsenic was elevated above background soil concentrations but was below recommended soil guidelines for the protection of human health.

Sample 12 was taken from within a hole on the drainage pads. The hole was symmetrical and appeared to be intentional. It is unclear what the use of this hole was. Arsenic was found to exceed the recommended soil guideline for the protection of human health.

Sample 15 was taken by using the pXRF directly on the timber of the fence line. This is ***not*** a soil sample. The elevated arsenic, copper and chromium indicate the timber is more than likely treated with copper chromium and arsenic.

Sample 21 was taken at depth in the same location as lab sample sheep 1. Arsenic was found to exceed the recommended soil guideline for the protection of human health.

Dieldrin

Two samples were analysed at the lab for a full heavy metal suite and OCP's. **Sheep 1** was taken at directly adjacent to where the spray unit exits into the drainage pads. At Sheep 1 sample location, dieldrin was found to be more than two times the recommended soil guideline for the protection of human health.

Sheep 2 was taken adjacent to the spray unit. Dieldrin in Sheep 2 was found to be elevated, but less than half the recommended soil guideline for the protection of human health.

Conclusions

Elevated arsenic and dieldrin were found in samples taken from close to the spray unit location. It is considered that the site has been impacted by sheep dipping activities. It appears that heavy metal concentrations, specifically arsenic, decrease with depth in the areas where depth samples were taken. Dieldrin concentrations in the samples taken show that directly adjacent to the unit has been impacted by dieldrin use (more than two times the guideline value for human health). However, the sample taken further away from the unit was below the guideline value for human health.

It is recommended that if the site is to be redeveloped or subject to future change of land use a detailed site investigation is completed to assist in decision making.

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Appendix A – Sampling maps

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Surface Sample Locations:

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Heat map of arsenic concentrations in surface samples:

Depth Sample Locations:

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Appendix B – Site photos

	Historic photo provided by site owner showing spray unit (Unknown date)
	Photo of spray unit area taken at approximately the same place as the historic image

Spray unit area and entrance to concrete drainage pads

View from woolshed looking across drainage pads towards the spray unit

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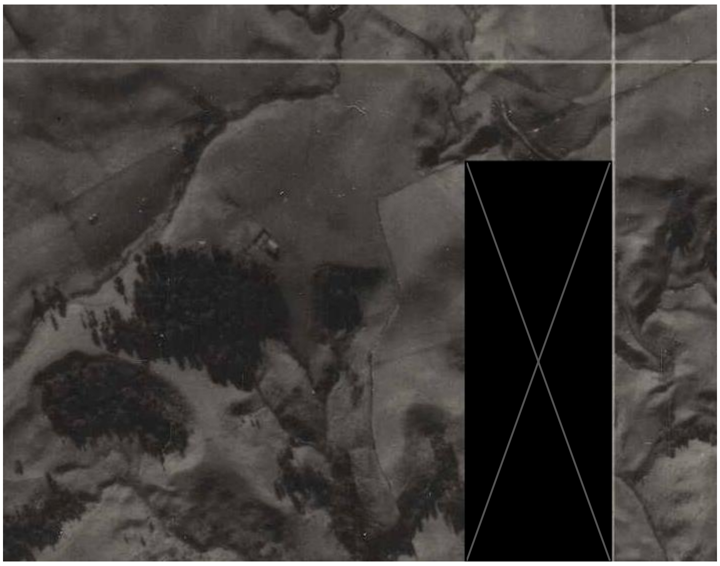
Chemical stored in HAZCHEM storage onsite that were historically used onsite (from left to right with active ingredient):

- Coopers sheep pour on - Famphur
- Organothiophosphate
- Coopers supreme D.F.F – Diflufenican
- Youngs sheep dip – Carbophenothion

Appendix C – Historic aerial imagery

	1950 [redacted]
	1966 [redacted]

	1981 [redacted]

	2010 – Google Earth
	2012 – Google Earth

20

	2016 – Google Earth

21

Appendix D – pXRF results

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Date	Time	Reading	Mode	Sample Name	Elapsed Time Total	Cr	Cr +/-	Cu	Cu +/-	Zn	Zn +/-	As	As +/-	Pb	Pb +/-
27/01/2022	9:53:44	1	Cal Check	Stainless plate	14.82										
27/01/2022	9:55:45	2	Soil	Soil Standard	87.96	46	4	112	4	368	5	88	6	1347	9
27/01/2022	9:58:03	3	Soil	SiO2 Blank	88.31	-26.8	2	-5.7	2	1.5	0.9	1.2	0.6	0.2	0.8
27/01/2022	10:02:41	4	Soil	Sample 4	88.42	12	5	2245	16	909	9	25.9	1.5	26.2	1.5
27/01/2022	10:21:34	5	Soil	Sample 5	87.59	53	3	1079	8	104	3	38.7	1.4	41.9	1.4
27/01/2022	10:26:36	6	Soil	Sample 6	88.28	0	4	10	2	64	2	10.4	1	12.2	1.2
27/01/2022	10:33:19	7	Soil	Sample 7	87.27	28	2	8.8	1.6	363	3	6.7	0.7	13.6	0.9
27/01/2022	10:45:07	8	Soil	Sample 8	87.45	18	2	32.8	2	316	3	11.4	0.8	12	0.8
27/01/2022	10:47:51	9	Soil	Sample 9	87.77	19	4	40	3	496	5	24.1	1.2	23.5	1.3
27/01/2022	10:51:34	10	Soil	Sample 10	87.44	38	3	12.1	1.9	44.4	1.5	4.1	0.8	12.1	1
27/01/2022	10:56:45	11	Soil	Sample 11	87.35	37	3	43	2	675	5	16.9	1	28.1	1.1
27/01/2022	10:59:36	12	Soil	Sample 12	87.18	42	3	25.7	1.9	133	2	27.1	1	19.3	1
27/01/2022	11:02:53	13	Soil	Sample 13	87.23	30	3	36	2	338	4	13.1	0.9	19.9	1
27/01/2022	11:05:52	14	Soil	Sample 14	87.03	35	3	55	2	886	6	24.5	1.1	33.2	1.1
27/01/2022	11:09:39	15	Soil	Sample 15 - Fence	87.64	5082	22	1310	9	89	2	3121	11	11.8	0.9
27/01/2022	11:15:40	16	Soil	Sample 16	87.51	31	2	10.3	1.7	107.3	2	6.3	0.7	10.8	0.9
27/01/2022	11:34:12	17	Soil	Soil Standard	88.03	51	4	122	4	362	5	76	6	1339	9
27/01/2022	11:36:10	18	Soil	SiO2 Blank	88.37	-29	2	-5	2	-1	0.8	-0.1	0.6	1.4	0.9
27/01/2022	11:38:11	19	Soil	Stainless plate	87.51	155558	1917	5587	122	-131	17	-305	15	530	26
27/01/2022	11:49:25	20	Soil	Sample 20	87.73	41	3	51	2	74.7	1.9	8.3	0.9	15.6	1.1
27/01/2022	11:52:53	21	Soil	Sample 21	86.92	37	3	44	2	906	6	20.1	0.9	23	1
27/01/2022	11:56:40	23	Soil	Sample 23	87.41	30	3	17.8	2	87.9	1.9	8.6	0.8	14.6	1
27/01/2022	11:58:20	24	Soil	Sample 24	87.82	32	3	20	2	35.4	1.5	3.8	0.8	9.2	1

Appendix E – Laboratory forms

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

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T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

SPv1

Client:	Waikato Regional Council	**Lab No:**	2854218
Contact:	WRC Labtest	**Date Received:**	03-Feb-2022
	C/- Waikato Regional Council	**Date Reported:**	14-Feb-2022
	Private Bag 3038	**Quote No:**	115446
	Waikato Mail Centre	**Order No:**	135777
	Hamilton 3240	**Client Reference:**	Soil Testing
		Submitted By:	Caitlin Holm

Sample Type: Soil

Sample Name:		Sheep 1 27-Jan-2022 11:38 am	Sheep 2 27-Jan-2022 11:43 am			
Lab Number:		2854218.1	2854218.2			
Individual Tests						
Dry Matter	g/100g as rcvd	59	73	-	-	-
Heavy Metals, Screen Level						
Total Recoverable Arsenic	mg/kg dry wt	38	10	-	-	-
Total Recoverable Cadmium	mg/kg dry wt	0.43	0.33	-	-	-
Total Recoverable Chromium	mg/kg dry wt	17	9	-	-	-
Total Recoverable Copper	mg/kg dry wt	105	75	-	-	-
Total Recoverable Lead	mg/kg dry wt	46	19.0	-	-	-
Total Recoverable Nickel	mg/kg dry wt	4	3	-	-	-
Total Recoverable Zinc	mg/kg dry wt	2,400	82	-	-	-
Organochlorine Pesticides Screening in Soil						
Aldrin	mg/kg dry wt	< 0.017	< 0.014	-	-	-
alpha-BHC	mg/kg dry wt	0.146	< 0.014	-	-	-
beta-BHC	mg/kg dry wt	0.139	0.021	-	-	-
delta-BHC	mg/kg dry wt	< 0.017	< 0.014	-	-	-
gamma-BHC (Lindane)	mg/kg dry wt	0.051	< 0.014	-	-	-
cis-Chlordane	mg/kg dry wt	< 0.017	< 0.014	-	-	-
trans-Chlordane	mg/kg dry wt	< 0.017	< 0.014	-	-	-
2,4'-DDD	mg/kg dry wt	< 0.017	< 0.014	-	-	-
4,4'-DDD	mg/kg dry wt	< 0.017	< 0.014	-	-	-
2,4'-DDE	mg/kg dry wt	< 0.017	< 0.014	-	-	-
4,4'-DDE	mg/kg dry wt	< 0.017	< 0.014	-	-	-
2,4'-DDT	mg/kg dry wt	< 0.017	< 0.014	-	-	-
4,4'-DDT	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Total DDT Isomers	mg/kg dry wt	< 0.10	< 0.09	-	-	-
Dieldrin	mg/kg dry wt	2.6	0.47	-	-	-
Endosulfan I	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Endosulfan II	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Endosulfan sulphate	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Endrin	mg/kg dry wt	0.036	< 0.014	-	-	-
Endrin aldehyde	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Endrin ketone	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Heptachlor	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Heptachlor epoxide	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Hexachlorobenzene	mg/kg dry wt	< 0.017	< 0.014	-	-	-
Methoxychlor	mg/kg dry wt	< 0.017	< 0.014	-	-	-

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked * or any comments and interpretations, which are not accredited.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-2
Heavy Metals, Screen Level	Dried sample, < 2mm fraction. Nitric/Hydrochloric acid digestion US EPA 200.2. Complies with NES Regulations. ICP-MS screen level, interference removal by Kinetic Energy Discrimination if required.	0.10 - 4 mg/kg dry wt	1-2
Organochlorine Pesticides Screening in Soil	Sonication extraction, GC-ECD analysis. Tested on as received sample. In-house based on US EPA 8081.	0.010 - 0.06 mg/kg dry wt	1-2
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) . gravimetry. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed). US EPA 3550.	0.10 g/100g as rcvd	1-2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 08-Feb-2022 and 14-Feb-2022. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix C: Summary of Reviewed Detailed Site Investigations

Region/District	Sheep Dip?	Foot bath?	Location	Report type	Year	Meets CLMG No.1?	Dip type	Sampling undertaken?	Sampling methodology	Contamination found?	Main contaminant	Levels	Depth Samples? Greater then 0.3m	Number of depth samples	Is lead elevated?	Year dip is first visible
Environment Canterbury	Y		Edward Street, Lincoln	DSI	2012	Y	n/a	Y	Lab analysis	Y	Arsenic, Lead, Aldrin & Dieldrin	Arsenic 85mg/kg Lead 700mg/kg Aldrin 0.094mg/kg Dieldrin 9.4mg/kg	N	0	Y	N/A
Environment Canterbury	Y	Y	126 Greenpark Road, Greenpark	DSI	2015	N	Spray race	Y	Composite	Y	Arsenic	Arsenic 24mg/kg	N	0	N	1973
Environment Canterbury	Y		1211 Main North Road, Woodend	DSI	2015	N	Plunge	Y	Lab analysis	Y	Arsenic + lead, copper & zinc	Arsenic 3900 mg/kg	Y	4	Mild	N/A
Environment Canterbury	Y		1535 Main South Road, Rolleston	DSI	2016	N	n/a	Y	Lab analysis	N			N	0		N/A
Environment Canterbury	Y		63 Constitution Road, Rotherham	DSI	2016	N	Spray Race	N		n/a			N	0		N/A
Environment Canterbury	Y		406 Southbridge Leeston Road, Southbridge	DSI	2017	N	Spray Race	Y	XRF + Lab Analysis	N			N	0		N/A
Environment Canterbury	Y		225-311 Worsleys Road, Christchurch	DSI	2015	N	Spray Race	Y	Lab analysis	Y	Arsenic	Arsenic 64mg/kg	N	0	N	1965
Environment Canterbury	Y		Kilworth Street, Methven	DSI	2016	N	Communal dip	Y	XRF + Lab Analysis	Y	Arsenic	Arsenic 680mg/kg Lead 220mg/kg	N	0	Y - On area of old building	1900
Environment Canterbury	Y		96 Woodstock Road, Canterbury	DSI	2014	N	n/a	N	n/a	n/a	n/a	n/a	N	0	n/a	N/A
Environment Canterbury	Y		Western Valley Road	DSI	2006	N	Spray Race	Y	Lab analysis	Y	Arsenic	Arsenic 21mg/kg	N	0	N	N/A
Environment Canterbury	Y		Telegraph Road, Darfield	DSI	2017	N	n/a	Y	Lab analysis	Y	Arsenic	Arsenic 871mg/kg	Y	23	Y	1940
Environment Canterbury	Y		Inland Road,Kaikoura	DSI	2006	N	Spray Race	Y	Lab analysis	Y	Arsenic & Dieldrin	Arsenic 41 mg/kg Dieldrin 5.44 mg/kg	Y	1	N	N/A
Environment Canterbury	Y		201 Halswell Road, Christchurch	DSI	2017	Y	Plunge dip replaced by spray race	Y	Lab analysis	Y	Arsenic, Lead & Dieldrin	Arsenic 112mg/kg Lead 645mg/kg Dieldrin 31mg/kg	Y	3	Y	1940: Dip 1984:Spray
Environment Canterbury	Y		280 Adams Road, Southbridge	DSI	2017	N	Plunge	Y	XRF + Lab Analysis	Y	Arsenic & Dieldrin	Arsenic 125mg/kg Dieldrin 1.79mg/kg	Y	3	N	1942
Environment Canterbury	Y		247 Nonoti Road, Cheviot	DSI	2017	N	n/a	Y	Lab analysis	Y	Arsenic	Arsenic 114mg/kg	Y	6	N	N/A
Environment Canterbury	Y		547 Hanmer Road, Doyleston	DSI	2018	N	Spray Race and plunge dip	Y	XRF + Lab Analysis	Y	Arsenic	Arsenic in plunge 2400mg/kg	N	0	N	N/A
Environment Canterbury	Y		247 Newtons Road, Rolleston	DSI	2018	N	Plunge	Y	XRF + Lab Analysis	Y	Dieldrin	Dieldrin 5.1mg/kg	N	0	N	1962

Environment Canterbury	Y	Hauschilds Road, Tai Tapu	DSI	2018	N	Spray Race	Y	XRF + Lab Analysis	N	n/a	n/a	N	0	N/a	N/A
Environment Canterbury	Y	Dawsons Road, Templeton	DSI	2018	N	n/a	Y	Lab analysis	n/a	?	?	N	0	?	N/A
Environment Canterbury	Y	151 Hoskyns Road, Rolleston	DSI	2019	N	Spray Race	Y	Lab analysis	Y	Arsenic	Arsenic 116mg/kg	N	0	N	N/A
Environment Canterbury	Y	783 Woodstock Road, Oxford	DSI	2020	N	n/a	Y	Lab analysis	Y	Arsenic	Arsenic 26.3mg/kg	N	0	N	N/A
Environment Canterbury	Y	587 Halswell Road, Kennedys Bush	DSI	2019	N	Spray Race	Y	Lab analysis	N	n/a	n/a	N	0	N	N/A
Environment Canterbury	Y	1160 Tram Road, Swannanoa	DSI	2020	Y	Plunge	Y	Lab analysis	N	n/a	n/a	Y	11	N	1980
Environment Canterbury	Y	97 Stott Drive, Darfield	DSI	2020	N	Plunge	Y	XRF + Lab Analysis	Y	Arsenic	Arsenic 196 mg/kg	N	0	n/a	1940
Environment Canterbury	Y	264 Milltown Road, Southbridge	DSI	2020	N	n/a	Y	Lab analysis	Y	Arsenic	Arsenic 173 mg/kg	N	0	Y	N/A
Environment Canterbury	Y	2143 Bealey Road, Hororata	DSI	2020	N	Spray Race	Y	Lab analysis	Y	Arsenic	Arsenic 62 mg/kg	N	0	N	N/A
Environment Canterbury	Y	280 Adams Road, Southbridge	DSI	2020	n/a	Plunge	-	-	n/a	-	-	N/A	N/A	-	N/A
Environment Canterbury	Y	Whincops Road, Halswell	DSI	2008	N	Plunge	Y	Lab analysis	Y	Arsenic	Arsenic 330 mg/kg	N	0	Y	N/A
Environment Canterbury	Y	Cardyle Street, Darfield	DSI	2004	N	n/a	Y	Lab analysis	Y	Arsenic	Arsenic 104 mg/kg	N	0	n/a	N/A
Environment Canterbury	Y	50 Sansovino Lane, Rolleston	DSI	2015	N	Plunge	Y	Lab Analysis	N	-	-	Y	1	-	N/A
Environment Canterbury	Y	Selwyn Quarries, Christchurch	DSI	2011	N	Plunge	Y	Lab Analysis	Y	Arsenic	Arsenic 98 mg/kg	Y	3	-	1942
Hamilton City Council	Y	Huntington	DSI	2004	n/a	Pot	-	-	n/a	-	-	N/A	N/A	-	N/A
Hamilton City Council	Y	Huntington	DSI	2001	n/a	Pot	Y	Lab Analysis	Y	Arsenic & Dieldrin	Arsenic 1350 mg/kg Dieldrin 2.45mg/kg	Y	26	-	1952
Hamilton City Council	Y	Huntington	DSI	2004	n/a	Pot	N	-	n/a	-	-	N	0	-	1952
Northland Regional Council	Y	204 Waipapa Road, Kerikeri	DSI	2016	Y	n/a	Y	Lab Analysis	Y	Arsenic	Arsenic 79 mg/kg	N	0	N	N/A
Environment Southland	Y	79A Kennington Waimatua Road, Invercargill	DSI	2015	Y	Plunge	Y	Lab Analysis	Y	Arsenic	Arsenic 2000 mg/kg	Y	3	Y	N/A
Environment Southland	Y	62 Donald Road, Edendale	DSI	2015	n/a	Dusting machine	Y	Lab Analysis	Y	Dieldrin	Dieldrin 6.1mg/kg	N	0	Y	N/A
Environment Southland	Y	80B Wallacetown, Lorneville	DSI	2013	N	Spray Race	Y	Lab Analysis	Y	Arsenic & Dieldrin	Arsenic 430 mg/kg Dieldrin 12.7 mg/kg	N	0	n/a	1956
Environment Southland	Y	Coyler Road, Invercargill	DSI	2013	N	Spray Race	Y	Lab analysis	N	-	-	N	0	-	N/A
Waikato Regional Council	Y	600 Onewhero-Tuakau Bridge Road, Tuakau	DSI	2016	Y	n/a	Y	Lab Analysis	Y	Arsenic	Arsenic 1800 mg/kg	Y	18	n/a	N/A
Waikato Regional Council	Y	600 Onewhero-Tuakau Bridge Road, Tuakau	DSI	2016	N	n/a	Y	Lab Analysis	Y	Arsenic & Dieldrin	Arsenic 1090 mg/kg Dieldrin 60 mg/kg	N	0	Y	N/A

Waikato Regional Council	Y	155 Newell Road, Hamilton	DSI	2016	N	n/a	Y	Lab Analysis	Y	Arsenic	Arsenic 39 mg/kg	N	0	N	N/A
Waikato Regional Council	Y	216 Parker Lane, Pukekohe	DSI	2018	N	n/a	Y	Lab Analysis	Y	Arsenic	Arsenic 40 mg/kg	N	0	n/a	N/A
Waikato Regional Council	Y	216 Parker Lane, Pukekohe	DSI	2017	N	n/a	Y	Lab Analysis	Y	Arsenic & Dieldrin	Arsenic 62 mg/kg Dieldrin 2.5 mg/kg	N	0	N	N/A
Bay of Plenty Regional Council	Y	Wellington Street, Opotiki	DSI	2006	N	Communal dip	Y	Lab Analysis	Y	Arsenic	Arsenic 189 mg/kg	N	0	n/a	1926
Bay of Plenty Regional Council	Y	Wellington Street, Opotiki	DSI	2011	N	Communal dip	Y	Lab analysis + XRF	Y	Arsenic	Arsenic 845 mg/kg	N	18	N	1926
Bay of Plenty Regional Council	Y	65 Gee Road, Owhata	DSI	2016	N	n/a	Y	Lab analysis	Y	Arsenic & Dieldrin	Arsenic 64 mg/kg Dieldrin 1.13 mg/kg	Y	18	N	N/A
Bay of Plenty Regional Council	Y	Corner Wharenui Road and Porikapa Road, Owhata	DSI	2019	Y	n/a	Y	Lab analysis + XRF	Y	Arsenic	Arsenic 590 mg/kg	Y	N/A	N	Prior to 1960
Bay of Plenty Regional Council	Y	Portion of Lakes Subdivision on Takitimu Drive, Tauranga	DSI	2013	N	n/a	Y	Lab analysis	n/a	Arsenic?		N	0		N/A

Appendix D: Public Survey Results

Are you aware of a sheep dip or spray unit on your property?	Would you like to remain anonymous?	How long have you owned the property? (If not applicable, please put N/A)	What is the main use of the farm where the dip/spray unit is/was located?	If 'Yes', is the dip/spray unit still in place? or has it been removed/	If there is/was a sheep dip on the property, what type of dip is it? (You can select multiple)	Which chemicals were used in the dip? (You can select multiple)	How long was the sheep dip/spray unit in use for approximately?	Was the dip used only by the farm of which its located? (i.e. did neighboring farmers also use the dip?)	Where was/is your dip located? (Tick all that apply or add your own response. Please be generic to ensure anonymity)	Where were the dipping chemicals stored?	Where were was the used dip fluid disposed?	Thanks for filling out this survey! Do you have any further information you would like to add?
No												
No												
Yes	Yes	30 year's	Sheep farming	Yes, its still in place	Spray dip	Unsure	Unsure.	Yes	Near woolshed, Near stockyards	Unsure	Into the paddock	Nope
Yes	Yes	N/A	Sheep farming	No, it has been removed	Pot dip	Unsure	15 years	Yes	Near woolshed, Near stockyards	Woolshed Chemshed	Filtered out over pd	
Yes	No	N/A	Sheep farming	It gets put away in a shed when not in use	Swim through dip, Spray dip, Portable dips/spray units (Units that are transported onsite then removed after use)	DDT, Arsenic, Cryozine	30 years + for the shower dip ,unknown for the plunge dip ,15 years for the modern jetting machine	Yes	Near woolshed, Near a stream, Near stockyards	Unknown for old dips ,modern jetter chemicals in chemical shed	Drained into sump	
Yes	Yes	35 years	Sheep farming	No, it has been removed	Pot dip	Arsenic, Unsure	Not sure. Maybe 40 years plus	Yes	Near woolshed, Near stockyards	In woolshed	Into yards	
Yes	No	3years, family farm since 1941	Beef now. Originally dairy, then sheep.	Yes, its still in place	Pot dip	Unsure	45years	Yes	Near woolshed	In the woolshed	Down the hill	
Yes	Yes	leased for 5 years	Sheep farming	Yes, its still in place	Plunge dip	Organic Phosphates (unsure of names - may be above?)	has been used for the past 60-70 years	Yes	Near woolshed	in a shed beside the dip	into a paddock	- side note.....edit the last question....not written right.
Yes	Yes	Five years	Sheep farming	Yes, its still in place	Swim through dip, Pot dip, Spray dip	DDT, Arsenic	Still getting used	Yes	Near woolshed, Near a stream	Lock up safe	In the pdck	
Yes	Yes	5 years	Sheep farming	Yes, its still in place	Portable dips/spray units (Units that are transported onsite then removed after use)	Unsure	5 years	Yes	Near woolshed, Near stockyards	Chem shed	No disposal needed	Ours is a electro run through dip with eye
Yes	No	4 years	Sheep farming	No, it has been removed	Spray dip	Unsure	10 years	Yes	Near woolshed	unsure	washed down to soak away	no
Yes	Yes		Sheep farming	Yes, its still in place	Portable dips/spray units (Units that are transported onsite then removed after use)	diflubenzuron and cyromazine	2 months	No, it was used by others	Near woolshed, Near stockyards	In the animal health cupboard		

Appendix E: Sheep Dip Study Flyer

Sheep Dip Study

LINK TO SURVEY:

https://forms.gle/esHWnncdhYtkZiEe7

I am master's student undertaking research through the University of Waikato on patterns of soil contamination around sheep dip locations. I am interested in talking to people that may:

- Have worked on a sheep farm
- Have operated a dip
- Own a farm with a dip/that used to have a dip (i.e. has been removed)
- People with general knowledge of sheep dips and their use.

I am also looking for sites to sample, so if you would like some further information regarding this please do not hesitate to get in touch.

I have included a link to an anonymous survey on the left side of this flyer with a bit more information and some broad questions to assist my research.

Please feel free to contact me via Facebook, email, or phone:

- **Caitlin Holm**
- **EMAIL**: ceh28@students.waikato.ac.nz
- **PHONE**: [redacted]

Appendix F: Letter Regarding Sheep Dip Study

Caitlin Holm
Email: ceh28@students.waikato.ac.nz
Phone: [redacted]

Dear Sir/Madam:

My name is Caitlin Holm and I am a masters student at The University of Waikato. I am currently undertaking my dissertation which is a small research project on sheep dips and the patterns of contamination found around dips.

I am sending this letter and a link to a questionnaire to find further information regarding dipping practices and in the hopes of potentially finding a few study sites.

I have created an online questionnaire which is completely anonymous with some questions regarding sheep dips and their dipping/spraying practices, the link to this is below:

https://forms.gle/KzpBichxmaNRenes5

I have attached a copy of the questionnaire for your reference and am also happy to go through this with you over the phone or via email.

In terms of study sites, I am hoping to receive access to current or former sheep dip site to undertake sampling, majority of which would be done using a portable analysis device which requires little to no soil disturbance. In return, I would provide a 1-page summary of the findings a sampling map showing areas of potential contamination and its extent.

If you are interested in chatting about this further, please do not hesitate to get in touch via phone or email. I would love to chat and receive any information you are comfortable passing on. Please feel to pass on this letter or my information to anyone you think may be interested in this study.

Sincerely,

Caitlin Holm