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TOWN OF ESPERANCE

Data Gap Analysis and Sampling and Analysis Plan

Submitted to:
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REPORT

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Executive Summary

Background

The Department of Transport (Transport) (formerly the Department of Planning and Infrastructure, DPI) contracted Golder Associates Pty Ltd (Golder) to develop "*the procedures and protocols*" for

- "*determining the extent of contamination of lead and nickel in Esperance";* and
- *"the sampling of homes and other premises to assess the cleaning requirements*".

This request was initiated as part of the Esperance Cleanup and Recovery Project (ECRP), a group organised by the Government of Western Australia to cleanup residues of lead carbonate and nickel sulphide to meet cleanup guidelines recommended by the Department of Health (DOH). The creation of the ECRP and the subsequent request followed concerns about fugitive lead and nickel dust emissions from the Esperance Port (the Port).

The request was structured into five tasks:

- *1 - To assess the sampling of 21 homes and advise whether this has been scientifically robust and accountable to determine the degree of contamination and the required cleaning;*
- *2 - To develop the procedures and protocols for the sampling of the Esperance townsite to determine the extent of contamination – Type "A" Sampling;*
- *3 - To develop the procedures and protocols for sampling, if required, to more accurately assess the delineation of contaminated and non-contaminated areas– Type "B" Sampling;*
- *4 - To develop the procedures and protocols for the sampling required to assess what cleaning is required of each individual premises [internal and external]-Type "C" Sampling; and*
- *5 - To develop the procedures and protocols for the sampling required to determine that the cleaning of individual premises [internal and external] has been satisfactorily undertaken –Type "D" Sampling.*

This document reports on the five tasks requested by Transport.

Golder has consulted with the *Contaminated Sites Management Series*, in particular the *Development of Sampling and Analysis Programs* published by the Department of Environmental Protection (DEP) now the Department of Environment and Conservation (DEC) (DEP, 2001),for direction in regards to the review of data in Task 1 and the construction of a *SAP* in Tasks 2 through 5. Furthermore, Golder has used Data Quality Objectives (DQO) as suggested by DEC during the Tasks to achieve the desired objectives.

This series of DEC documents provides useful guidance for the development of this sampling and analysis plan. The *Development of Sampling and Analysis Programs* (DEP, 2001) is the guidance for developing sampling and analysis programmes for the assessment of the presence and extent of environmental contamination in Western Australia. These guidelines are not only used for sites that are contaminated to assess the extent of contamination in an environmental setting but are also routinely used for the basis of sampling and analysis plans for a variety of pollution incidents on land and water, e.g. the former Waste Control Site at Bellevue. Importantly the guidelines provide guidance on the frequency of sampling to achieve an appropriate level of confidence on whether or not additional action may be required.

Task 1 – Assessment of Sampling of 21 Homes

As per the request for quotation (RFQ), the objectives for Task 1 were to advise whether the sampling of 21 homes within Esperance was:

- "*adequate to determine the degree of contamination in these homes; and*

- *adequate for determining the level of cleaning required*."

Golder reviewed the sampling methodology provided by Transport and quality assurance and quality control (QA/QC) methodology available for each type of sampling against guidance on environmental sampling and analysis *(DEP, 2001)* as well as from the related Australian Standards quoted in this document.

Golder's review of the sampling of 21 homes found that the data provided a preliminary indication of contamination within each of the 21 homes based on the ECRP designated guidelines and could be used to refine the areas within the home that needed to be cleaned. Notwithstanding, because of a lack of information regarding sampling methodology and QA/QC documentation, the sampling programme did not meet regulatory guidelines. Consequently, there is considerable uncertainty in the interpretation of the results.

Task 2 – "Type A" Sampling

The second task was developing a *SAP* for "Type A" samples to assess the extent of lead and nickel contamination in Esperance. Concentrations of lead and nickel in soil previously reported from sampling by regulatory agencies have indicated that the majority of concentrations were below the screening levels of 300 mg/kg for lead and 600 mg/kg for nickel. We have taken this into account in describing several different responses depending on the outcomes of the "Type A" sampling. In addition, we recommend that a rainwater sample be taken if a rainwater tank is located in close proximity to soil sampling points and some limited internal samples taken in residential premises. Our approach includes detailing the requirements of a proper field sampling programme, the types of samples to be collected and reviewing various sampling designs and subsequently providing a sampling design to achieve the stated objectives.

We have recommended a stratified/judgmental sampling design for "Type A" sampling based on concentric circles originating from the Port with sampling points on these circles at 250 m intervals, producing a total of 302 sampling points within the Esperance town site as well as Nulsen, Chadwick, West Beach, Sinclair, and Castletown.

Analyses of composite soil samples using a Niton X-Ray Fluorescence Spectroscopy (XRF) analyser has been suggested for "Type A" sampling as the primary sampling method, at or within a 20 m radius of the sampling points identified by Golder. As a quality control measure, composite soil samples should be analysed by a laboratory technique at a rate of 10% (1 in 10 samples) to verify that the XRF readings are accurate.

Rainwater tank sampling is to be undertaken where a rainwater tank is present on the premises at or near the sampling points and should be sampled in accordance with *AS/NZS 5667.1:1998 Water quality — Sampling Part 1.*

Judgemental interior swab sampling is recommended to allow comparison with lead and nickel concentrations in soil and rainwater. Swab sampling should be undertaken according to *AS 4874-2000* and US Occupational Safety and Health Association guidance.

Sampling should be conducted using a tiered approach to assess the extent of the sampling to be undertaken as distance increases from the Port, e.g.:

- collect samples from identified locations in the first three concentric sample locations;
- analyse samples for lead and nickel concentrations;
- assess whether additional sampling is required; and
- repeat procedure if required.

As the results of the "Type A" sampling is not known, Golder has proposed a number of responses to undertake Task 3 depending on the outcome of "Type A" sampling. These include:

- **Outcome 1** – If the concentrations of lead and nickel in the composite soil sample analysed by XRF are higher than 60 mg/kg and 120 mg/kg, respectively (20% of regulatory guideline), the individual sub-samples must be analysed to assess whether a hotspot that exceeds regulatory guidelines exists at the sampling location. If a soil sub-sample result and/or the rainwater and/or interior swab results are above recommended DOH clean up guidelines (Section 5.0) then go to “Type B” sampling within a 20 m radius of the sampling point with results above the clean up guidelines. Furthermore, review results of the “Type A” sampling to assess whether contours of contamination are discernable. If contours are discernable, then these areas would also progress to “Type B” sampling.

- **Outcome 2** – If soil sub-sample results, rainwater and interior swab results are below recommended DOH clean up guidelines, or if composite soil samples are below 20% of guideline levels, then review sampling results to assess whether contours of elevated soil concentrations are discernable. If contours are discernable, then these areas would progress to “Type B” sampling. If contours are not discernable (i.e. results appear random), then identify sample locations in which the lead and nickel concentrations are in the highest 10th percentile of the distribution and undertake “Type B” sampling within 20 m of each location.

- **Outcome 3** - In addition to the selection of “Type B” sampling locations based on the potential outcomes of “Type A” sampling discussed above, Golder also recommends “Type B” sampling is undertaken according to the following:
  - “Type B” sampling is undertaken at locations in Esperance where historical data collected by regulatory authorities (DEC, DOH etc) including rainwater, plant, dust, soil and human blood exceeds the relevant health-based criteria and guidelines for lead and/or nickel.

Task 3 – “Type B” Sampling

The third task of this project was developing a *SAP* to assess which homes would need cleaning within an area that may have elevated levels of lead and nickel (as assessed by “Type A” sampling). The “Type B” *SAP* incorporates more intensive composite soil sampling as well as drip zone soil sampling in the front, back and side yards of selected premises.

Results from both “Type A” and “Type B” sampling should be reviewed and compared to the DOH adopted clean-up guideline levels for lead and nickel to assess whether “Type C” sampling is recommended at each premises.

Task 4 – “Type C” Sampling

The objective of the “Type C” sampling design was to “*develop the procedures and protocols for the internal and external assessment of homes and other premises*” for contamination with lead and/or nickel. The sampling methodology recommended by Golder for “Type C” sampling incorporates sampling of media inside and outside premises and includes rainwater and dust.

The methods for collecting dust samples include surface swab and vacuum sampling of interior and exterior surfaces. A standard set of sample locations is recommended for each premises as well as judgemental sampling where deemed appropriate by the sampler.

Results of “Type C” sampling should be compared with the clean-up guidelines recommended by the DOH. The ECRP should use professional judgement when reviewing results from sampling media for which clean-up guidelines have not been established e.g. roof spaces.

Task 5 – “Type D” Sampling

The objective of “Type D” sampling design was to provide analytical data that the ECRP can use to assess whether the cleaning of premises in Esperance after “Type C” sampling was satisfactory.

“Type D” sampling should only be carried out at locations where clean-up was undertaken, e.g. if only internal surfaces were cleaned, then only the internal surfaces should be assessed by “Type D” sampling.

Preferably, “Type D” samples should be taken as close as possible to the “Type B” and “Type C” sample location.

This Executive Summary should be read in conjunction with the main report and is not intended to be a standalone document.

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1.0 INTRODUCTION

Golder Associates Pty Ltd (Golder) submitted a tender to the Department of Transport (Transport) (formerly the Department for Planning and Infrastructure, DPI) on 11 June 2009 in response to the Request For Quotation (RFQ) DPI 203709 for a staged project as part of the Esperance Cleanup and Recovery Project (ECRP). The ECRP has been set up by the Government of Western Australia to cleanup residues of lead carbonate and nickel sulphide to meet cleanup guidelines recommended by the Department of Health (DOH). The request followed concerns about fugitive lead and nickel dust emissions from the Esperance Port (the Port).

Golder was subsequently awarded the contract by Transport on 3 July 2009. Transport is the agency responsible for managing the ECRP. Other stakeholders involved in this project include the DOH, Department of Environment and Conservation (DEC), Chemistry Centre of WA (ChemCentre) and the Shire of Esperance.

A Steering Committee (SC) has been established to oversee and facilitate the ECRP. This SC includes officers from relevant State Government agencies (DOH, DEC, LandCorp, Transport), the Shire of Esperance and community representatives, including the Esperance Chamber of Commerce and Industry.

The SC has established a Working Group on Sampling (WGS), which will oversee the development of the *Sampling and Analysis Plan (SAP)*. The WGS will make a recommendation in regards to the *SAP* to the SC, and once adopted, the *SAP* will be implemented by the ECRP team. It is understood by Golder that this report will be provided to the SC for use during sampling.

2.0 BACKGROUND

In December 2006, the Esperance community noticed a significant number of bird deaths in and around the town. DEC was also receiving an increasing number of complaints regarding dusts and odour from the Port. At the time, the Port handled products that included iron ore, nickel sulphide and lead carbonate as well as grains, fertilisers and fuel. Tests on the birds revealed their bodies contained elevated levels of lead.

As concern about the bird deaths escalated, the regulatory agencies collected environmental samples including, soil, grass, tank water, marine sediment, marine organisms and swabs from surfaces in and around buildings. The DOH also provided a blood lead analysis service for residents of Esperance. Rainwater tanks had lead and nickel levels exceeding Australian Drinking Water Guidelines (ADWG) and a number of residents had blood lead levels above DOH target value of 5 µg/dL.

The DOH has indicated lead dust is the greatest source of non-occupational exposure to lead. It can settle on the ground and on surfaces in and around your home (DOH, 2009). The community have also raised concerns regarding the levels of lead and nickel contamination from the testing done throughout Esperance town site. The community have requested a sampling and analysis programme be undertaken to ascertain areas of elevated levels of lead and nickel and subsequently a cleaning programme to mitigate exposure to these elevated levels.

In 2007, homes where children had blood lead levels above 5 µg/dL were cleaned by the Port (Esperance Port, 2009). These homes were resampled in 2009 as part of the ECRP activities.

As part of the ECRP, a trial sampling of 21 homes was conducted to assess which areas within homes needed to be cleaned. Three of the homes sampled had been previously cleaned in 2007. Samples were collected from soil, roof cavities, ceiling spaces, interior and exterior surfaces, carpets and rainwater tanks. The sampling performed during this trial is reviewed in Section 6.0.

ECRP are running other projects associated with cleaning of homes including a remobilisation project to assess whether recontamination is occurring from ambient air remobilisation of lead residues in the Esperance town site.

The *SAP* reported in this document is designed as a multi-staged approach for assessing levels of lead and nickel within the Esperance town site. “Type A” sampling is designed as an initial indication of potential contamination and defining areas where further testing may be required (see Section 5.0). “Type B” sampling is designed to further refine areas of contamination (see Section 8.0) and “Type C” sampling is designed to assist in assigning priorities to homes that need cleaning (see Section 9.0). “Type D” sampling (see Section 10.0) is designed to assess whether the cleaning of homes was adequate.

Golder acknowledges that the ECRP will *develop Standard Operating Procedures (SOP) for various elements of the sampling project*, including further information in regards to sampling methodologies that should be employed and number of samples to be collected, *based on Australian Standards* (ECRP, 2009).

3.0 SCOPE OF WORKS

As part of the ECRP activities, Transport has commissioned Golder to provide guidance on the sampling design to assess which homes within Esperance are to be cleaned. Transport developed a scope of works as outlined in their RFQ and has recommended a staged approach to sampling within the Esperance town site. The RFQ outlined the following tasks:

- *1 - To assess the sampling of 21 homes and advise whether this has been scientifically robust and accountable to determine the degree of contamination and the required cleaning;*
- *2 - To develop the procedures and protocols for the sampling of the Esperance townsite to determine the extent of contamination – Type “A” Sampling;*
- *3 - To develop the procedures and protocols for sampling, if required, to more accurately assess the delineation of contaminated and non-contaminated areas– Type “B” Sampling;*
- *4 - To develop the procedures and protocols for the sampling required to assess what cleaning is required of each individual premises [internal and external]-Type “C” Sampling; and*
- *5 - To develop the procedures and protocols for the sampling required to determine that the cleaning of individual premises [internal and external] has been satisfactorily undertaken –Type “D” Sampling*.

This report presents the results of the five tasks of the project.

4.0 OBJECTIVES

Prior to designing a *SAP*, the DEC (DEP, 2001) suggests defining the objectives of the sampling programme to establish suitable sample types to be collected, sampling locations, analysis parameters and analytical detection limits.

As part of the *Contaminated Sites Management Series*, in particular the *Development of Sampling and Analysis Programs* (DEP, 2001), DEC suggests the use of Data Quality Objectives (DQO) to achieve those objectives and incorporate them into the *SAP*. The DEP (2001) document is included in Appendix A.

DEC refers to Australian Standard (AS) *4482.1 – 2005 Guide to the investigation and sampling of sites with potentially contaminated soil*, which provides guidance on the use of DQO. *AS 4482.1-2005* defines DQO as “*qualitative and quantitative statements that clarify study objectives derived from the output of each of the following steps of the DQO process:*

a) *Clarification of the study objective.*

b) *Definition of the most appropriate type of data to collect.*

c) *Determination of the most appropriate conditions from which to collect the data.*

d) *Specification of acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.*

e) *Evaluation of the data collected and confirmation that the objectives have been met.”*

The DQO process, as defined by the US Environmental Protection Agency (US EPA, 2000), is broken down into seven steps or elements, namely:

1) **State the problem** – concisely describe the problem to be solved. Review prior studies and existing information to gain a sufficient understanding to define the problem. See Section 2.0.
2) **Identify the decision** – identify what questions the study will attempt to resolve and what actions may result. See Sections 6.1, 6.4, 7.1 and 7.4.
3) **Identify inputs to the decision** – identify the information that needs to be obtained and the measurements that need to support the decision. See Section 7.4.
4) **Define the study boundaries** – Specify the spatial and temporal aspects to which the decisions will apply. See Sections 7.4 and 11.6.
5) **Develop a decision rule** – define a statistical parameter of interest, specify the action levels and integrate the previous planning process outputs into a single statement that describes the logical basis for choosing among alternative actions. See Sections 5.0 and 7.5.6. Field and laboratory QA/QC programmes are discussed in Section 11.0.
6) **Specify limits on decision errors** – define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision. This is discussed in Sections 7.5.3 and 7.5.6. Field and laboratory QA/QC programmes are discussed in Section 11.0.
7) **Optimise the design for obtaining data** – evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design to meet the planning process objectives. See Section 7.4.

5.0 CLEANUP GUIDELINES

The cleanup guidelines to be applied to lead and nickel residues in Esperance have been recommended by DOH and endorsed by the ECRP SC are presented in Table 1 (reproduced from the RFQ).

Table 1: Clean-up Guidelines Recommended by Department of Health

Sampling Media	Lead	Nickel
Soils	300 mg/kg	600 mg/kg
Rainwater tanks	0.01 mg/L	0.02 mg/L
Internal surfaces and external surfaces accessed by young children	0.04 µg/cm^2	N/A
Internal and external surfaces readily accessed by adults	0.4 µg/cm^2	N/A
Roof spaces and ceiling voids	TBD*	N/A
External Roof surfaces	TBD	N/I**
* "TBD" was not described in the RFQ; ** N/I = no information included in the RFQ		

5.1 Background Levels of Lead

Soil samples were collected from Albany to assess background levels of lead and nickel in soil in an environment similar to Esperance except for the shipment of these materials through the Port.

The results from soil sampling conducted by officers of DOH and the ChemCentre in Albany (*Brief ECRP Sampling of 21 Homes 5 June* & *Appendix 1 Albany samples 11-05-09ww*) were reviewed. Results of 24 samples from Albany were compared with results of soil samples collected in Esperance during the sampling of 21 homes in February 2009.

Esperance results were available in:

- Excel spreadsheet "*MD090715 08E1450 residents from DOH*";
- Excel spreadsheet "*MD090715 08E1454 RESIDENTIAL from DOH*"; and
- Excel spreadsheet "*MD090715 08E1465 RESIDENTS from DOH*".

The mean value for lead concentrations in soil samples from Albany was the same as for soil samples from Esperance (19.47 mg/kg and 19.17 mg/kg, respectively). The Albany mean result for lead was influenced by a higher value in the Albany results (one lead result in Albany was 220 mg/kg). The effect of this higher value is not as evident when reviewing the median results, where the Albany lead result was lower than the Esperance lead result (2.55 mg/kg and 6.05 mg/kg, respectively).

The mean data for Albany lead samples with the elevated lead value removed was also reviewed.

Nickel results in Albany were lower than in Esperance, with a mean of 2.02 mg/kg in Albany and a mean of 18.3 mg/kg in Esperance.

Table 2 provides a summary of the results from the Esperance and Albany soil sampling.

Table 2: Comparison of Lead and Nickel Soil Results in Esperance and Albany

Parameter	Esperance Pb	Albany Pb	Albany Pb (highest value removed)	Esperance Ni	Albany Ni
Number of Samples	58	24	23	58	24
Minimum	1.1	0.25*	0.25*	0.5	0.5
Maximum	190	220	140	200	12
Mean	19.17	19.47	10.75	18.3	2.02
Median	6.05	2.55	2.4	7	1
Standard Deviation	35.44	51.21	28.9	32.84	2.87

*For samples below the limit of detection (LOD), half of the LOD was used for statistical analysis (i.e. LOD/2).

The difference between the results was also reviewed to assess whether there was a statistically significant difference between the lead and nickel results in Esperance versus background samples collected in Albany. A two tailed *t*-test for samples with unequal variance resulted in the following p-values for lead and nickel:

- Lead result (including higher value): $p = 0.98$.
- Lead result (excluding higher value): $p = 0.27$.
- Nickel result: $p = 0.0004$.

These p-values suggest that results for lead were not statistically significant ($p > 0.05$) but nickel results were statistically significant ($p < 0.05$).

Analysis of the Esperance and Albany data suggests that the difference in lead results is negligible in the context of soil samples and is not a statistically significant difference. Nickel results show a statistically significant difference, which may be due to the historical export of nickel from the Port in Esperance. Soil sample results were below the health investigation levels of 300 mg/kg for lead and 600 mg/kg for nickel. The range of sample results in Esperance and Albany suggests that lead and nickel results can vary significantly from location to location. These variations in results may be due to factors such as the exact sample location (e.g. industrial vs. residential), wind factors and topographical factors. These factors make it difficult to derive a background value; therefore, Golder's sampling design does not include the use of these background levels when reviewing analytical results. Instead, Golder focuses the sample design on distance from the Port to assess whether declines in concentrations of lead and nickel in soil are evident with increasing distance from the Port.

6.0 TASK 1 – GAP ANALYSIS

6.1 Objectives and Methodology

The first task to be undertaken was a gap analysis of the sampling and analytical programme carried out by the ECRP on 21 homes in the Esperance town site. As per the RFQ, the objectives for Task 1 were to:

- *assess the sampling of 21 homes and advise whether this has been scientifically robust and accountable to determine the degree of contamination and the required cleaning; and*
- *develop the procedures and protocols for the sampling of the Esperance townsite to determine the extent of contamination – Type "A" Sampling.*

The investigation in the 21 homes included soil sampling as well as sampling of surfaces in and around the premises.

Consequently, we have used the DEC guidelines on the assessment and management of contaminated sites as guidance for assessing the adequacy of the studies undertaken and the development of the SAP.

In Western Australia, the DEC "*is responsible for protecting and conserving the environment and nature of Western Australia*". As part of this responsibility, the DEC has published a series of administrative and technical guidelines to help with the identification, assessment, management and remediation of contaminated sites in Western Australia.

The DEC technical guidelines titled *Development of Sampling and Analysis Programs* (DEP, 2001) provides guidance on developing sampling and analysis programmes for assessing whether or not contamination exists in an environmental medium. These guidelines are not only used to assess the extent of contamination for sites that are known to be contaminated, but are also routinely used to develop sampling and analysis plans for a variety of pollution incidents on land and water e.g. former Waste Control site in Bellevue. The soil screening values that have been adopted for the cleanup by ECRP (Table 1) are the health investigation levels for lead and nickel which are also sourced from these documents. Importantly the DEC guidelines provide advice on the frequency of sampling to achieve an appropriate level of confidence on whether or not additional action or investigation may be required.

Other guidelines, e.g. swab sampling methodology, have also been used in the assessment as appropriate.

The following sections provide a review of the sampling methodology and sample results to satisfy the stated objectives.

6.2 Information Provided

Transport provided the following documents to Golder for review in the gap analysis and for use in developing the SAP:

- *Esperance Cleanup and Recovery Project Update*, 20 July 2009, Wayne Winchester;
- *Briefing note: Esperance Cleanup and Recovery Project Intensive Sampling of Twenty One (21) Homes*;
- *Briefing note to the Minister for Transport, Esperance Cleanup and Recovery Project*, DT/09/00051/1;
- *Surface Swab Sampling for Lead*, ChemCentre;
- *Soil Sampling for Lead and Nickel*, ChemCentre;

- *Carpet sampling protocol*, ChemCentre;
- *Procedures for cleaning homes and other premises*, Draft 6, Esperance Cleanup and Recovery Project;
- *Environmental background sampling program for lead and nickel in household dusts (Albany) and Unidentified house dusts and testing results from Albany, WA, Appendix 1, 11-5-09*;
- *Sample location map* (21 homes);
- Excel spreadsheet "*MD090715 08E1450 residents from DOH*";
- Excel spreadsheet "*MD090715 08E1454 RESIDENTIAL from DOH*";
- Excel spreadsheet "*MD090715 08E1465 RESIDENTS from DOH*";
- *Esperance House Sampling Protocols Draft*, ChemCentre; and
- Handouts from a PowerPoint presentation "*Esperance Cleanup and Recovery Project and EsPA Air Quality Monitoring Data*".

6.3 Purpose of Sampling

The sampling of the 21 homes was conducted on 23-26 February 2009 by officers from the DOH, the ChemCentre and the Shire of Esperance. The ECRP has advised that the purpose of this sampling programme was to:

- *gain a general indication of the current concentrations of lead and nickel in relation to the distance from the Port;*
- *identify the likely locations of contamination in and around premises;*
- *determine whether homes cleaned in 2007 have remained free from contamination;* and
- *assist in the development of sampling and cleaning protocols.*

6.4 General Sampling Methodology

The ECRP selected 21 homes at approximately 500 m intervals along four transect lines radiating out from the Port to the suburbs of West Beach, Sinclair, Nulsen and Castletown. ECRP advised that a range of old and new home types were sampled, including three homes that had been previously cleaned. Approximately 20 samples were collected at each property from areas described by ECRP as "*outside areas, inside areas, ceiling voids, roof spaces, garages/carports, rainwater tanks and garden areas*" (ECRP, undated$_a$). ECRP advised that they "*deliberately looked for areas where dust would accumulate – hunted for dusty areas both inside and outside homes*" (ECRP, undated$_b$). A total of 396 samples were collected from the 21 homes. A summary of the sample types is shown in Table 3.

6.5 Data Collection

The minimum requirements for sampling from environmental media as part of a sampling and analysis plan for a contaminated site are outlined in the DEP (2001) document. The sampling of the 21 homes in Esperance will be compared to DEC guidelines in the first instance or internationally recognised guidelines if the DEC guidelines are not suitable. The following sections describe and assess the methodology used by the ECRP and summarise results of the data collected from the 21 homes in Esperance.

6.5.1 Soil

ECRP provided Golder with guidelines used by the ChemCentre for soil sampling for lead and nickel. This ChemCentre document describes the equipment that was recommended for sampling and how to collect a soil sample. The general method recommended by ChemCentre is to collect a "*composite sample*" from four to eight surface spots (sub-samples) at a depth of 0-4 inches (0-10 cm). When sampling children's play areas, the ChemCentre recommended four to eight sub-samples and collecting the top two inches (5 cm) of soil. For samples collected from a garden, the ChemCentre recommended a minimum of three sub-samples from the first six to eight inches (15-20 cm) of soil (the root zone).

It was not clear from reviewing the data submitted how many sub-samples (or whether the sub-samples size was recorded) were included in each composite sample collected during the sampling programme in Esperance and Albany. This lack of information makes it difficult to compare the results with regulatory values (DEP, 2001).

The ChemCentre recommended making a "*map of your sample locations if more than one sample*" but there was no mention of mapping the sample locations when more than one sample was collected. There was also no mention of the use of chain of custody documentation throughout the sampling process.

The ChemCentre methodology recommended that "*to determine whether the property as a whole is contaminated*" you collect "*a random sampling over the entire property of at least ten separate, non-composited samples*". There was no information supplied to indicate what the ChemCentre based this recommendation on.

The DEC (DEP, 2001) advise that when interpreting data from composite samples, it is important "*to be aware that as the data only shows an average concentration and there are likely to be higher or lower concentrations in situ*". Subsequently, the DEC recommend that composite sampling is used as an initial screening tool only and that "*due to the fact that composite samples do not provide an indication of the possible maximum contaminant concentrations, the results from composite sampling cannot be used for health or ecological risk assessments*".

The DEC also advises that when composite sampling is used, that each sample is made up from the same number of constituent samples, the constituent samples are equal in size and that a composite sample includes no more than four constituent samples (DEP, 2001).

In addition, *AS 4482.1—2005* states that "*while compositing samples is sometimes used for confirming that little or no contamination is present and for preliminary site investigations to facilitate the planning of more detailed work, composite sampling alone is generally unsuitable for the definitive assessment of site contamination due to the inherent uncertainties in the resultant data*". A comprehensive guide on the composite sampling of soils is contained within Appendix B of *AS 4482.1—2005*. This guide points out that field compositing is inherently inaccurate and it is recommended that compositing is undertaken in a laboratory. There is no reference in the information provided by Transport to Golder as to whether the compositing of soil samples was done in the field or in a laboratory, however, as the samples were collected in Esperance and analysed in Perth, Golder has assumed they were field composites and therefore do not meet the Australian Standard.

The DEC guidance for the minimum number of sampling points for site characterisation based on detection of circular hot spots using a systematic grid sampling pattern (DEP, 2001) recommends five sampling points per 500 m^2 area. Although information on the land size (excluding residences) of the 21 homes sampled was not available, it is expected to be less than 500 m^2. A total of 58 soil samples were collected, of which 25 samples were described as composite samples and two were duplicates. An average of 2.7 soil samples was collected per residence. Overall, the number of soil samples would meet DEC guidance but with respect to the reliability of the data, the QA/QC information did not meet regulatory guidance (see Section 6.5.6). Nickel concentrations ranged from < 1 to 200 mg/kg and lead concentrations ranged from 1.1 to 190 mg/kg. These results are below the health investigation levels agreed to by Transport (Table 1, Section 5.0).

Table 3: Summary of Samples Taken from 21 Homes

Property	Soil	Interior Swab	Exterior Swab	Roof Swab	Dust e.g. carpet	Rainwater	Plant	QA/QC	Total Samples	QA/QC type
ESP 3.3	4	4	6	2	4		1		21	
ESP 4.3	3	7	6	1	3	1		1	22	Dust (carpet) blank
ESP 1.2	3	4	4	3	3	1			18	
ESP 5.1	2	5	3		2	1		1	14	Swab blank
ESP 7.3	2	8	4	2	4	1	1		22	
ESP 6.3	2	8	3	1	2				16	
ESP 2.1	2	4	3	2	2				13	
ESP 11.3	3	6	4	2	4	1		1	21	
ESP 12.1	3	5	3	2	3				16	
ESP 19	4	9	3	2	2	1		1	22	Swab blank
ESP 9.1	3	7	2	2	2	1			17	
ESP 13.2	1	9	3	2	3	1			19	
ESP 8.1	2	7	3	2	3				17	
ESP 20	2	8	2	2	2	1	1		18	
ESP 15.1	2	6	3	2	3				16	
ESP 17.1	3	6	2	3	3	2			19	
ESP 16.3	4	7	4	2	3			1	21	Swab blank
ESP 18.1	4	6	3	2	3		1		19	
ESP 10.1	2	7	2	2	3			2	18	Dust "container blank" and "New pogo"
ESP 21	4	7	4	3	4				22	
ESP 14.1	3	10	2	2	5		1	2	25	Swab "template blank" and dust "filter blank"
Total	**58**	**140**	**69**	**41**	**63**	**11**	**5**	**9**	**396**	

6.5.2 Swab Samples

There are no Australian standards or guidelines on the collection of surface swab samples. The swabs used in sampling were Ghost Wipes™. Ghost Wipes™ meet the American Society of Testing Materials (ASTM) International Standard *ASTM E1792 - 03 Standard Specification for Wipe Sampling Materials for Lead in Surface Dust* specifications for sampling materials for lead in surface dust and the specifications of the US Department of Labor Occupational Safety & Health Administration (OSHA, 1988) Method *ID-125G Metal and Metalloid Particulates in Workplace Atmospheres (ICP Analysis)*.

The Australian Standard *AS 4874 – 2000 Guide to the investigation of potentially contaminated soil and deposited dust as a source of lead available to humans* advises that emphasis be placed on the collection of house dust from surfaces at the following locations:

- *near entries to the house (particularly within the first metre);*
- *hallways; and*
- *beneath windows that open.*

The US Environmental Protection Authority (US EPA, 2008) has produced the guidance document "*Guidance for the sampling of lead in indoor residential dust for use in the integrated exposure uptake biokinetic (IEUBK) model*". The purpose of this guidance document is to recommend methods for collecting and analysing indoor residential dust data to estimate the mean concentration of lead in dust for use in the IEUBK model. While the data collected from the 21 homes in Esperance were not intended for use in this model, the recommendations of the US EPA provide technical guidance for collection of indoor dust for lead. The US EPA recommends that indoor dust samples (dust wipe or vacuum) for lead analysis be collected:

- *from either a bedroom of a child who is < 7 years old (< 84 months) or any bedroom if children are not present in the home;*
- *in the most frequently used living space (preferably by children < 7 years old (< 84 months), if present; and*
- *just inside the most frequently used entrance to the home.*

In many cases, the dust swab sampling at each Esperance residence included samples taken from one or more bedrooms, in "*lounge*" or living areas and from a windowsill. It did not appear that samples were taken from within entrances to the homes or hallways. While a description of the sample location was provided in the Excel spreadsheet of sampling results, the exact sampling location was unclear. A sketch of the residence including annotations of each sample location would have been a useful addition to this sampling plan.

The ChemCentre methods describe submitting the sample with a "*sample submission form*". It is not clear if this is a chain of custody document as it was not available for review in this gap analysis. Golder has assumed that a "*sample collection sheet*" is an alternative document to a chain of custody form. The ChemCentre recommended using a 10 cm^2 template when sampling, but there is no mention of cleaning the template between sampling or using disposable templates. The method indicated by the ChemCentre is adequate, however, they describe wearing a disposable glove "*on the hand in which you will do the sampling*". It is best practice to wear a disposable powderless glove on each hand while doing environmental sampling. In addition, it is recommended that gloves are changed after the template is applied to the surface i.e. before the swab is opened or touched. *AS 4874 – 2000* recommends that the sampling template and collection is not handled with bare hands.

A total of 140 interior swabs, 69 exterior swabs (including two duplicates), and 41 roof swabs (including two duplicates) were collected. The Excel spreadsheet provided to Golder contained data described as "*roof swabs*"; however, it was not clear whether these swabs were taken from an internal or an external roof surface. Consequently, Golder contacted Transport for clarification (27 July 2009, email from Papadopoulos to Devenish) and we were advised (28 July 2009, email to Papadopoulos) that "*no external roof surfaces* *were sampled*". Data described as "*roof swabs*" are therefore assumed by Golder to be sampled from internal roof surfaces.

The internal swab nickel and lead concentrations ranged < 0.005 – 1.2 µg/cm^2 and < 0.005 – 3 µg/cm^2, respectively. The external swab nickel and lead concentrations ranged < 0.005 – 3 µg/cm^2 and < 0.005 – 0.63 µg/cm^2, respectively. The roof swab nickel and lead concentrations ranged < 0.005 – 11 µg/cm^2 and < 0.005 – 6.7 µg/cm^2, respectively. The range of results indicates that there were exceedances in the adopted Transport guidance levels for lead of 0.4 and 0.04 µg/cm^2 for lead on internal and external areas accessible by adults and areas accessible by children, respectively. Exceedances of the adopted Transport guidance levels may trigger clean up in these areas. No guidance levels have been adopted by Transport for acceptable levels of nickel on interior or exterior surfaces. Furthermore, no guidance level has been adopted by Transport for concentrations of lead in roof spaces.

6.5.3 Dust

AS 4874 – 2000 provides guidance on vacuum sampling of dust that is a potential source of lead. The ASTM international standard *ASTM D7144 - 05a Standard Practice for Collection of Surface Dust by Micro-vacuum Sampling for Subsequent Metals Determination* provides guidance on dust collection from surfaces that cannot be reliably sampled using wipe collection methods, such as carpet. The ChemCentre methodology provided to Golder for the dust collection process is described as "*based on the SKC Operating instructions for their propriety carpet sampling kit, designed for sampling indoor contaminants such as pollens, moulds and dust mite*". Information on the specific equipment used, equipment decontamination process between sampling, and chain of custody documents was not supplied. Without this information, Golder is unable to comment on whether a suitable guideline such as *AS 4874 – 2000* or *ASTM D7144-05a* was followed.

A total of 63 dust samples, including two duplicates, were collected from carpet in the 21 homes. Carpet dust nickel and lead concentrations were < 0.005 – 0.16 µg/cm^2 and < 0.005 – 0.8 µg/cm^2, respectively. No guidance criteria have been adopted by the ECRP SC for acceptable levels of lead and nickel in carpet dust samples.

6.5.4 Rainwater

There are no Australian Guidelines available specifically on the collection of water samples from domestic rainwater tanks and no guidance provided in the DEP (2001) document. The ADWG provided by the National Health and Medical Research Council (NHMRC) provide information regarding preventative measures that should be taken to reduce a hazard or minimise the hazard to an acceptable level. Further information regarding guidance on the use of rainwater tanks is available in *Guidance on Use of Rainwater Tanks* (enHealth, 2004).

AS/NZS 5667.1:1998 Water quality—Sampling Part 1 provides guidance on water sample containers, sample identification and transport and sample preservation. *AS/NZS 5667.1:1998* recommends the inclusion of the following information in a "*sampling report*":

- *location (and name) of sampling site, with coordinates and any other relevant locational information;*
- *details of sampling point;*
- *date of sampling;*
- *method of sampling;*
- *time of sampling;*
- *name of sampler;*
- *general environmental and climatic conditions;*

- *nature of pre-treatment;*
- *preservation procedure;*
- *data gathered in the field; and*
- *any information which may affect the results of the analysis.*

The ChemCentre collection methodology provided to Golder describes collecting the rainwater samples in the supplied Polythene sample bottle “*prepared for low level metals analysis*” (ChemCentre, undated). It is stated in the ChemCentre method that pre-flushing is not necessary. The recording of the following parameters on a “*sample collection sheet*” was recommended by the ChemCentre:

- *tank material (plastic, Colourbond ®, galvanised iron, etc);*
- *age of tank (years, estimate if unknown);*
- *type of outlet (brass, plastic, other);*
- *roof collection type (if different from that previously recorded for the home); and*
- *first flush device fitted.*

No “*sample collection sheets*” with the above information were available for this gap analysis. The ChemCentre methodology does not mention the use of gloves during sampling.

A total of 11 rainwater samples were collected. No duplicate samples were taken. Rainwater nickel and lead concentrations ranged < 0.001 – 0.29 mg/L and 0.0004 – 0.034 mg/L, respectively. In some cases, rainwater nickel and lead concentrations in rainwater tanks exceeded the adopted ADWG guidance levels of 0.01 mg/L for lead and 0.02 mg/L for nickel. These exceedances may trigger the cleaning of these rainwater tanks.

6.5.5 Plants

There are no Australian standards or guidelines for the collection of plants for metals analysis and no guidance in the DEP (2001) document. From a human health perspective, the concentrations of metals in plants are important for consumption of the plants. The data provided to Golder on plants have been assessed from this basis and on the general QA/QC factors listed in Section 6.5.6.

The Australia New Zealand Food Standards Code 2000 published by Food Standards Australia New Zealand (FSANZ) has maximum levels (MLs) for contaminants and natural toxicants in food (FSANZ, 2008; Table 4). The ML is the maximum concentration of a specified contaminant, or specified natural toxicant, which is permitted to be present in a nominated food.

Table 4: Maximum Levels for Lead in Food

Food	Maximum Level (mg/kg)
	Lead
Brassicas	0.3
Cereals, Pulses and Legumes	0.2
Edible offal of cattle, sheep, pig and poultry	0.5
Fish	0.5
Fruit	0.1
Infant formulae	0.02

Food	Maximum Level (mg/kg)
	Lead
Meat of cattle, sheep, pig and poultry (excluding offal)	0.1
Molluscs	2
Vegetables (except brassicas)	0.1

Source: FSANZ 2008 Standard 1.4.2

There are no MLs set for nickel. In a review of processing aids (other than enzymes) conducted in 2006, FSANZ(2006) reported that nickel was not of a toxicological concern as it "…*has low systemic toxicity by the oral route, no evidence for carcinogenicity in either humans or experimental animals, only low residues in food expected.*"

Results for analysis of lead and nickel content in five plant samples were provided however, there were no sampling methods provided for plant sampling and no QA/QC data. One plant was described as "*plant, rear lattice*" but no other information was available. Two samples were silverbeet and one was cabbage leaf, while the remaining sample was pumpkin foliage.

Plant nickel concentrations were < 0.5 mg/kg and lead concentrations ranged < 0.05 – 0.09 mg/kg. Lead concentrations do not exceed the adopted FSANZ MLs for brassicas and vegetables of 0.3 mg/kg and 0.1 mg/kg, respectively. No MLs are available for nickel for comparison.

6.5.6 Quality Assurance and Quality Control (QA/QC)

The following sections outline the QA/QC procedures as recommended by the DEC in sampling and analysis plans (see Appendix A).

6.5.6.1 Field Blanks

The DEC guidelines state that "*at least one field blank should be taken per sampling team per trip per collection apparatus*" (DEP, 2001). The field blank samples taken in the sampling programme comprised five field swab blanks and two field dust blanks (one described as '*carpet*'). A minimum of one swab blank was taken per day of sampling. A carpet dust field blank was taken on the first two days of sampling but not on the third day, 25 February 2009. No other field blanks were collected. This does not comply with the DEC guidance.

Concentrations of nickel and lead detected in the field blank, swab samples were below the limit of detection (0.005 µg/cm^2) with the exception of swab field blanks for lead at ESP 19 (0.006 µg/cm^2), ESP 5.1 (0.01 µg/cm^2), and ESP 11.3 (0.006 µg/cm^2). There was no indication of whether these values were subtracted from the values for the samples taken at these locations. Nickel results were below the detection limit of for all field blank samples collected.

6.5.6.2 Rinsate Blanks

Rinsate blanks are used to demonstrate that the sampling equipment used has not contaminated the samples. No rinsate blanks were taken on the field sampling equipment, in particular the soil sampling equipment. Although the ChemCentre soil sampling methodology described cleaning the sampling equipment by "*scrubbing with detergent and rinsing at least three times in clean water*", there was no validation of this cleaning method. Golder considers it is standard industry practice that deionised water is used during the cleaning of equipment or where this is not practicable, for the last rinse of equipment.

6.5.6.3 Container and Other Blanks

DEC guidelines state "*at least one container blank should be collected per group of samples*" (DEP, 2001). A dust container blank, a dust filter blank, and a "*template blank*" were collected during the sampling period.

No container blanks were taken for soil, rainwater or swab samples. This does not comply with the DEC guidance. No methodology was provided for the container blanks.

Concentrations of nickel and lead detected in these samples were below the limit of detection (0.005 µg/cm^2) with the exception of the template blank at ESP 14.1 (0.009 µg/cm^2 for lead and nickel).

No transport blanks were taken. The DEC recommends one transport blank per group of samples (DEP, 2001).

6.5.6.4 Field Duplicate and Triplicate Samples

The DEC recommends one field duplicate sample be taken for every 20 investigative samples (DEP, 2001). Two dust (carpet) field duplicates, two soil duplicates, two roof swab duplicates and two external swab duplicates were analysed in this study. No chain of custody documentation was supplied to Golder. The descriptions of the data in the Excel spreadsheets supplied to Golder were very brief. Consequently, we were not able to assess which duplicate sample matched with which primary sample. No internal swab field duplicates, rainwater duplicates or plant duplicates were taken. The number of field duplicates taken in this study does not meet DEC guidance.

AS 4482.1 - 2005 recommends for every 20 soil samples a "*split sample*" is taken to check on the analytical proficiency of the laboratory, with one replicate sample from each set submitted to a different laboratory for analysis. No triplicate samples i.e. a sample sent to a secondary laboratory, were taken during the sampling period.

6.5.7 Summary of Data Gaps

Data gaps were identified in the data supplied to Golder from the sampling of 21 homes in Esperance. The data gaps were as follows:

- In general, information on sampling methodologies was not sufficient to assess if they meet regulatory guidelines. From the information supplied, we have assessed that the soil sampling method did not strictly follow *AS 4482.1 – 2005* and *AS 4874 – 2000* and the choice of sampling locations for dust swab and vacuum samples did not strictly follow *AS 4874 – 2000*. Methodology for sampling of plants was not supplied. The carpet dust sampling methodology lacked detail and was not assessed against *ASTM D7144 - 05a*. The rainwater sampling methodology was brief and was not assessed against *AS/NZS 5667.1:1998*.
- Laboratory reports, chain of custody documents and information on sample holding times and transport conditions were missing, which are needed to assess the validity of these data.
- The number of QA/QC samples collected did not meet DEC guideline levels.

6.6 Conclusions

The purpose of the gap analysis was to assess whether or not the sampling and analytical programme undertaken for the 21 homes was robust and would allow conclusions about the extent of contamination and cleaning needed in these homes and whether or not the sampling methods and QA/QC procedures were adequate.

The data collected from the 21 homes cover a range of different environmental media. The total number of samples taken at each residence ranged from 14 to 25 including QA/QC samples, with an average of 18.9 samples. Eighteen of the 21 homes were selected for sampling based on four transects radiating from the Port to the four suburbs of West Beach, Sinclair, Nulsen and Castletown. A further three homes were chosen from those that had been previously cleaned. Golder considers this method of selecting residences to sample was suitable for a preliminary assessment but may need to be reconsidered for a detailed study of the Esperance town site.

We have compared the data provided with known regulatory guidance including the DEP (2001) document and relevant Australian and international standards. Generally, the minimum requirements of the DEC guidance on sampling and analysis plans (DEP, 2001) and several Australian standards were not met in the sampling carried out on the 21 homes in Esperance, which introduces some uncertainty in the quality and integrity of these data. Nevertheless, these data may be used for the purposes of a preliminary screening study.

The following points summarise the outcomes of this gap analysis in terms of the objectives for this report:

- some of the data collection in this sampling programme was undertaken in accordance with established methods and procedural standards, however, QA/QC procedures were not followed in many instances;
- these data provide a preliminary indication of the extent of contamination within the 21 homes sampled due to the collection of a reasonable number of samples from several different environmental media in each home;
- these data may give an indication of the location of contamination in the homes sampled, however, data gaps exist surrounding the choice of sampling locations, particularly dust samples, so this information is considered by Golder to be preliminary;
- if Golder assumes that the requirement for cleaning of a home is indicated by exceedance of the ECRP designated guidelines (see Section 5.0) in each media tested, then the sampling programme does give an indication of the extent of cleaning needed in each home tested;
- these data are not sufficiently robust to allow conclusions about the general distribution of contamination in Esperance due to the small number of homes that were sampled, the small area selected and the uncertainties around the reliability and integrity of these data; and
- these data are not sufficiently robust to provide guidance on additional testing that might be needed to delineate the extent of contamination in Esperance.

7.0 TASK 2 – “TYPE A” SAMPLING AND ANALYSIS

7.1 Objectives

The second task outlined in the Transport RFQ was “*determining the extent of lead contamination in the Esperance townsite*”. In our proposal, we suggested developing a *SAP* for “Type A” samples to assess the distribution of lead and nickel in soil in the first instance, with additional judgemental or stratified random sampling of rainwater or building interiors.

Previous testing by regulatory agencies indicated that, in the main, the concentrations of lead and nickel in Esperance soil were below the screening health investigation levels of 300 mg/kg and 600 mg/kg, respectively. Notwithstanding, the distribution of lead and nickel levels in soil may provide important information on which areas to undertake more intensive sampling.

In the Sections that follow, we consider a number of possible outcomes of the soil sampling and recommend additional investigations for each, including sampling of other media (e.g. rainwater) in addition to soil.

The following sections provide a detailed *SAP* to address Transport’s request for sampling throughout the Esperance town site in a systematic and scientifically robust manner.

The sections include information regarding sampling strategy, sampling methodology, recommendations following the receipt of sample results, and QA/QC considerations during the sampling.

7.2 Contaminants of Concern

Transport has specified that the *SAP* will focus on lead and nickel as the contaminants of concern.

7.3 Sampling Strategy

The sampling strategy we have developed incorporates various sampling techniques to provide a comprehensive, statistically significant and logistically feasible sampling programme. The techniques that were considered included:

- **Simple random sampling** - Locations for sampling are chosen in advance using a proper randomising method; hence, all locations have an equal chance of being chosen for sampling, even after an adjacent location has been chosen.
- **Stratified random sampling** - Areas likely to have higher concentrations of contaminants, or higher variability of contaminants, are selected (thus "stratifying" the design), then sampled, normally at a higher frequency than the other areas. Sampling within designated areas needs to be properly randomised, as above.
- **Systematic sampling** - Samples are collected in a regular pattern, for example, along specified radii (transects), or on points of a grid. The pattern used depends on the information available about the area.
- **Judgemental sampling** - Samples are collected in locations that are chosen based on professional judgement, based on knowledge of the site contamination. This method is usually combined with other designs.

7.3.1 Soil Sampling Frequency for Contaminated Sites Investigation

The minimum number of sampling points to characterise a site based on detection of circular hot spots using a systematic grid sampling pattern as recommended by the DEC (DEP, 2001) does not provide guidance for sites larger than five hectares (50,000 m^2). Such sites are usually subdivided into smaller areas for more effective sampling. The area encompassed by the 11 arcs in Figure 1 is approximately 3,608 hectares. This can be subdivided into approximately 721 smaller areas of five hectares each, with sampling beginning at the Port and progressively moving out to incorporate the whole Esperance town site. The minimum number of sampling points recommended by the DEC per five-hectare area is 55; therefore, 39,655 samples would need to be taken in the area outlined in Figure 1. Although this frequency of sampling would give a 95% confidence of detecting hotspot contamination, this frequency of sampling is not warranted, given previous investigation results and the source of lead and nickel. Lead and nickel were shipped through the Port of Esperance; hence, there is likely to be a relationship between the source and the distribution of lead and nickel to the surrounding area.

Golder has provided an alternate sampling approach based on a combination of systematic sampling and judgmental sampling for assessing the distribution of lead and nickel in Esperance.

It is imperative that the sampling team read the following sampling design and methodology provided to achieve a successful outcome.

7.4 “Type A” Sample Design

The “Type A” sampling has been designed to assist in identifying areas that might require more detailed investigation under “Type B” or “Type C” sampling. The sampling design recommended for “Type A” sampling consists of eleven (11) concentric circles originating from the Port spaced 500 m apart. Sampling points were selected on these concentric circles in 250 m intervals, resulting in 302 sampling points within the Esperance town site as well as Nulsen, Chadwick, West Beach, Sinclair, and Castletown. The distance between these arcs could be decreased to incorporate more sample points.

We recommend that composite soil sampling be performed at each sampling point for x-ray fluorescence spectroscopy (XRF) testing as per Section 7.5.2. We also recommend that a rainwater sample be taken when a soil sample is collected in premises that have a rainwater tank, and that judgemental interior swab samples are also collected from the premises. Figure 1 illustrates the suggested sampling locations for the “Type A” sampling.

The arcs were based on distance from the Port as this is thought to be the source of lead and nickel contamination. The arc design is based on the assumption that deposition of dusts will decrease with increasing distance from the Port. Wind may be a factor in the manner by which dust is deposited in Esperance and would be evident if sample results suggested that certain trajectories away from the Port had higher concentrations of lead and/or nickel than other trajectories. These factors would be considered in the "Type B" sample analysis (Section 7.5.6).

Golder suggests that sampling be divided into seven rounds as follows:

- **Round 1** – Arc 1 through Arc 3 (30 sample points).
- **Round 2** – Arc 4 and Arc 5 (36 sample points).
- **Round 3** – Arc 6 and Arc 7 (55 sample points).
- **Round 4** – Arc 8 (39 sample points).
- **Round 5** – Arc 9 (45 sample points).
- **Round 6** – Arc 10 (50 sample points).
- **Round 7** – Arc 11 (47 sample points).

It is recommended that samples from each round are analysed and reviewed prior to the commencement of sampling the next round. If review of analytical results indicates that sample results are significantly lower than the previous round, sampling can cease. For example, if sampling from Round 3 indicates that sample results are significantly lower than those reported for Round 2, then Round 4 does not need to commence. A flowchart to assist compliance with the proposed sampling design is provided in Section 7.5.6.

To assess whether there is a significant decrease in sample results, it is recommended that statistical analysis be performed to assess the significance of the data. The recommended statistical method adopted depends on the properties of the data set collected by the sampling (e.g. the number of samples collected, the distribution of the data, and the existence of outliers in the data). Golder recommends that the data be assessed by a suitably qualified person to decide on the appropriate statistical method to be used.

The methodology described above is based on an objective of broadly identifying where more detailed sampling may be required. Therefore as part of this methodology there is an option to review results and cease sampling if significantly lower results were identified between each sampling arc. This was to enable the more intensive sampling to be undertaken in the most affected areas. Subsequent to the development of this methodology, Transport has advised Golder that it plans to carry out soil sampling across the entire townsite without the option to cease sampling if significantly lower results are identified between arcs. The collection of a more comprehensive dataset is always preferable in a site assessment. In this case Transport has indicated it has sufficient resources to carry out soil sampling across the townsite so the Type A sampling methodology should be used as a guide for this process but should not limit Transport in the number and/or location of sample collection provided it is in excess of the recommendations.

As the outcomes of the sampling are not known, it may be necessary to use professional judgement in cases where analytical results do not show clear contours of contamination. Further discussion regarding outcomes from the sampling programme is provided in Section 7.5.6.

7.4.1 Sample Location

The purpose of this *SAP* is to provide information regarding areas of contamination from lead and nickel in Esperance. It is recommended that sampling locations be considered in the context of finding areas of contamination and choosing areas where there is a high risk of exposure to contaminants.

Sample points in Figure 1 are only suggested locations and may not be accessible or may not be located in an area considered suitable for sampling (i.e. the exact sampling point may be on asphalt or located in a home). Therefore, Golder recommends that targeted sampling be undertaken within a 20 m radius of the suggested sampling point (e.g. nearest residence or open land).

The following locations are considered satisfactory for the purposes of this *SAP* and have been ranked by order of preference. Golder understands that gaining permission to collect soil samples on residential properties may be difficult, therefore, sampling along the road or verge is a suitable alternative, though it is recommended that this is clearly noted on the field sampling forms or chain of custody documentation. Permission from residents to collect rainwater samples and swab samples from surfaces inside the premises will also be required.

When the sampling location falls within a residential area, preferably collect samples from:

- **Children's play area** – Areas including sandboxes or places where play equipment suggests high use by children are recommended as priority areas for soil sampling. Judgemental swab sampling of interior surfaces of premises that children can access is recommended.
- **Back yard** - Residents may be exposed to lead and/or nickel in their back yards due to frequent activity in these areas, Golder recommends that soil samples be collected primarily from backyards of residential properties during “Type A” sampling.
- **Front yard** – Residents may also frequent their front yard so they are considered suitable for the purposes of this sampling programme.

See Figures C, D and E for more direction on collecting samples from yard areas.

When the sampling location falls outside a residential area, collect samples from:

- **Recreational open space** - As these areas tend to be frequented by residents as well as visitors.
- **Along road or verge** – If samples cannot be collected from the areas stated above, it may be suitable to sample along the road or a verge. In these cases, it is recommended that samples be collected as far from the road as practicable (closer to the footpath) to prevent bias from the accumulation of lead from the historical use of leaded petrol.

As this sampling programme has been suggested in regards to finding areas of contamination, it is recommended that samples be collected from areas that are “expected” areas of contamination (e.g. underneath drains or under drip lines), as these areas would represent hot-spot areas of contamination and would provide information regarding where further sampling and subsequent cleaning should be performed.

When reviewing data, knowing the exact location of a sample will assist in evaluating the results in the context of the sample location, therefore, it is suggested that the GPS coordinates and a description of the sample location is collected for each sample during sample collection. Furthermore, it is recommended that a photograph be taken of each sample point for future reference.

This *SAP* focuses on lead and nickel dust deposits from Port operations. Therefore, Golder proposes sampling the top 3 cm of soil to characterise the soils that may have been impacted by the Port operations. The depth from which the sample was collected should also be noted.

Rainwater samples should be collected from the tap of the rainwater tank after flushing for 15-30 seconds to clear the water sitting in the tank pipes. This flushing will depend on the location and length of the pipes associated with the external tap of the tank. This is to be at the sampler's discretion and noted on the chain of custody report.

A flowchart (Figure A) detailing the recommended steps to assess where to take a sample has been provided below.

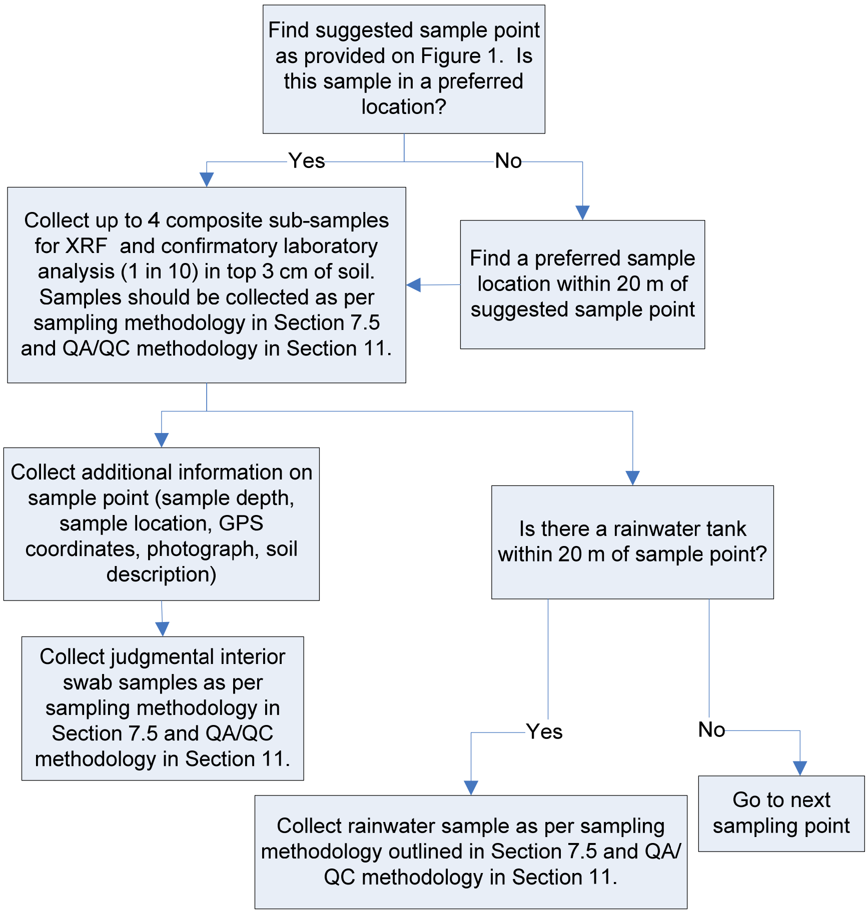

Figure A: Flowchart of Steps Taken to Select a Sample Point for "Type A" Sampling

7.5 Sampling Methodology

Composite soil sampling using a field-portable Niton XRF has been suggested for "Type A" sampling as the primary sampling method. As a quality control measure, soil samples should be collected for laboratory analysis at a rate of 10% (1 in 10 samples) to verify that the XRF readings are accurate.

Rainwater tank sampling is to be undertaken in accordance with *AS/NZS 5667.1:1998*.

Interior swab sampling is to be undertaken according to *AS 4874-2000* and US Occupational Safety and Health Association guidance.

The following sections provide information regarding composite sampling and the sampling methodologies suggested for the sampling programme.

7.5.1 Composite Sampling

Composite soil sampling has been suggested for this *SAP* as an initial screening tool to assess general levels of contamination at each sampling point as noted on Figure 1. Composite sampling can provide screening level information and is recommended only as a screening tool and not for health or ecological risk assessments (DEP, 2001).

A description of the proposed sampling methodology is provided below:

1) Locate the sample point suggested on Figure 1;

2) Identify areas within a radius of 20 m of the sample point that are accessible;

3) Collect up to four sub-samples of equal size within a radius of 20 m of the sample point and keep separate. Collect the same number of sub-samples for each composite sample throughout the programme for consistency. Make sure to collect enough sample material for each sub-sample so that:

    a. sub-samples can be composited;

    b. confirmatory laboratory analysis can be performed on 10% of samples;

    c. QA/QC samples can be collected (duplicate and triplicate samples at the rate of 1 in 20) (see Section 11.1); and

    d. Individual sub-samples can be analysed if the concentrations in the composite sample are above guideline levels (see Step #8);

4) Make notes regarding the sample location, soil type, depth of sample (top 3 cm recommended), photograph and GPS coordinates for each sub-sample;

5) Take sub-samples back to the laboratory;

6) Take the same amount of sample material from each sub-sample to create a composite sample and analyse with XRF (see Section 7.5.2) and by laboratory analysis for 10% of samples (see Section 7.5.3). Each discrete sub-sample must be thoroughly homogenised in the laboratory, rather than in the field before drawing the composite. Each discrete sub-sample must contribute an equal amount of material to the composite (refer *AS 4482.1-2005* for details on composite sampling);

7) Compare composite sample results with 20% of the guideline values (60 mg/kg for lead and 120 mg/kg for nickel)[1];

8) If results are above 20% of either guideline value, perform laboratory analysis on each individual sub-sample to assist in determining the exact area where there may be elevated results;

9) If sub-sample results are above 300 mg/kg for lead or 600 mg/kg for nickel, then consider Outcome 1 in Section 7.5.6; and

10) If sub-sample results are below 300 mg/kg for lead or 600 mg/kg for nickel, then consider Outcome 2 in Section 7.5.6.

7.5.2 XRF Sampling

An XRF is a tool that can be used to measure lead and nickel concentrations in soil, as well as other metals and metalloids. The US EPA has provided guidance on the use and reliability of XRF sampling in Method 6200, *Field Portable X-Ray Fluorescence Spectrometry* [FPXRF] *for the Determination of Elemental Concentrations in Soil and Sediment* (US EPA, 2007).

An XRF can be used for *in situ* testing or samples can be prepared for *ex situ* testing. *In situ* testing is recommended only as a screening tool due to "*the heterogeneous nature of the soil sample*". The accuracy of *ex situ* testing is assessed by the sample preparation and quality control measures are implemented (US EPA, 2007). Transport has advised that the XRF testing will be performed *ex situ* to minimise costs related to number of XRF'S out in the field at one time.

According to the US EPA, "*generally, instrument precision is the least significant source of error in FPXRF analysis. User- or application-related error is generally more significant and varies with each site and method used*". US EPA provides information regarding the common sources of user- or application-related errors; these discussed below:

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[1] According to DEC guidance (DEP, 2001), the guideline value used for composite sampling should be divided by the number of sub-samples collected. To be conservative, Golder has suggested that composite sample results are compared to 20% of the guideline value (equivalent to dividing the guideline value by 5).

1) **Physical matrix effects** – Parameters such as *particle size, uniformity, homogeneity and surface condition* can affect readings.

2) **Moisture content** – The overall error from moisture is minimal when moisture content is between 5 and 20%.

3) **Inconsistent positioning of samples in front of the XRF window** – Can produce errors in readings because "*the x-ray signal decreases as the distance from the radioactive source increases*".

To minimise these interferences, the following sampling preparation is recommended (US EPA, 2007):

1) *Each sample should be oven-dried for 2 to 4 hr at a temperature of less than 150º C.* Microwaving is not recommended because *"field studies have shown that microwave drying can increase variability between FPXRF data and confirmatory analysis and because metal fragments in the sample can cause arcing to occur in a microwave*. *When the sample is dry, all large organic debris and non-representative material, such as twigs, leaves, roots, insects, asphalt, and rock should be removed. The sample should be homogenised and then a representative portion ground with a mortar and pestle or other mechanical means, prior to passing through a 60-mesh sieve. Only the coarse rock fraction should remain on the screen.*

2) *The sample should be homogenised by using a riffle splitter or by placing 150 to 200 g of the dried, sieved sample on a piece of kraft or butcher paper about 1.5 by 1.5 feet in size. Each corner of the paper should be lifted alternately, rolling the soil over on itself and toward the opposite corner. The soil should be rolled on itself 20 times. Approximately 5 g of the sample should then be removed and placed in a sample cup for FPXRF analysis. The rest of the prepared sample should be sent off site for ICP or AA analysis. The method used for confirmatory analysis should meet the data quality objectives of the project.*

The limitations of the XRF should be clearly understood by the sampling team who should refer to the manual for the specific XRF being used for guidance. The US EPA method 6200 (US EPA, 2007) provides further information about using an XRF for environmental sampling. Golder recommends that this document is referred to prior to conducting sampling with an XRF.

Golder recommends developing a sampling and analytical plan for the type of XRF to be used as guidance by the sampling and analytical team.

7.5.3 Soil Sampling for Laboratory Analysis

In addition to XRF sampling, 10% of composite soil samples should be analysed for lead and nickel by a laboratory using a standard analytical method for metals. This equates to approximately 31 samples for laboratory analysis if 302 composite samples are collected for XRF analysis. This will provide an estimate of the correlation between XRF and laboratory results and the precision and accuracy of the XRF sampler. Confirmatory samples should be spread out throughout the programme to track the performance of the XRF (e.g. 1 in every 10 samples). If results from XRF and the laboratory analyses have an RPD > 50% (see Section 11.3), then the procedures for analysis by XRF need to be reviewed and the method recalibrated.

Confirmatory samples must be analysed by a NATA-accredited laboratory for lead and nickel. Standard detection limits available at NATA-accredited laboratories are suitable for this investigation as guideline values are 300 mg/kg for lead and 600 mg/kg for nickel, concentrations that are sufficiently higher than current laboratory limits of detection for metals.

7.5.4 Rainwater Sampling for Laboratory Analysis

Golder proposes that rainwater be sampled and the results compared with the drinking water guidelines recommended by the DOH and presented in Table 1.

When a rainwater sample is taken, information on characteristics of tanks and catchment are to be collected using a combination of discussions with the owner and field observations. The information to be noted, based on the recommendations in *AS/NZS 5667.1:1998*, include:

- location (and name) of sampling site, with coordinates and any other relevant locational information;
- date of sampling;
- method of sampling;
- time of sampling;
- name of sampler;
- general environmental and climatic conditions;
- the construction material and status of the roof and guttering;
- presence of lead flashings and/or pipes;
- presence of trees overhanging or nearby the roof;
- construction material of the tank;
- the age of the tank;
- previous cleanings of the tank; and
- whether or not the tank has a first flush device.

Please refer to Appendix B for a recommended observational sheet to be used by the sampling team during this process. We note that only limited information may be obtained because of access or ability to interview the residents. In such cases, the reasons for the limited information must be noted on the observational sheet.

Dissolved metals (filtered samples) are usually the type of samples collected for assessment against ADWG. However. it is proposed that unfiltered analytical data be collected to assess the concentration of metals that may be ingested in water as well as suspended matter. Golder recommends the following rainwater sampling methodology:

1) Apply QA and QC field procedures as outlined in Section 11.0;
2) Remove filtration devices or cloth material used as such from the rainwater tank tap outlet;
3) Turn on tap of rainwater tank and allow a steady stream of rainwater to flow for 15-30 seconds, collecting this water for discarding later;
4) Undo lids of sample bottles and hold opening of bottle under the water stream;
5) Fill bottles minimising air pockets that may result whilst filling, but do not overflow;
6) Re-cap bottles immediately. Wipe down the outside of the bottles;
7) Reinstate filtration devices in tank if present;
8) Place bottle in a chilled cooler as soon as possible; and
9) Fill other sample bottles.

7.5.5 Judgemental Interior Swab Sampling

There are no Australian standards or guidelines specifically on the collection of surface swab samples. *AS 4874-2000* includes some guidance on "*wipe sampling*" of surfaces for lead. Previous surface swab sampling in Esperance (done by the Pollution Response Unit of DEC and the DOH) adopted the US Occupational Safety and Health Association method ID-125G sampling methodology (US DOL OSHA, 2002). In this *SAP*, the swab sampling methodology for the collection of interior samples adopts some of the OSHA and *AS 4874-2000* principles.

Golder recommends taking up to five surface swab samples from the interior of the premises in locations based on the professional judgement of the sampler and including areas within the premises that can be accessed by young children.

The swab sampling methodology recommended for "Type A" sampling is as follows:

- Apply QA and QC field procedures as outlined in Section 11.0.
- Swabs should be supplied by the laboratory undertaking the swab analysis. Some of the considerations that a laboratory may take into account when choosing appropriate swabs are the concentrations of metals within the swabs and whether they dissolve easily for laboratory analysis.
- Swabbing should occur on a non-porous surface using a disposable template of 10 cm × 10 cm which should be replaced with a new template at each sample location to avoid cross-contamination. Using a template allows for results to be quantitatively expressed as both the concentration (µg contaminant / g dust) and the surface loading (µg/cm^2). The swab sampling should be done according to the step-by-step method outlined below.
- Templates should be handled with clean powderless gloves. The template should be taped onto the surface in a manner that minimizes disruption of dust. A new pair of clean powderless gloves should be used during the swabbing process.

A step-by-step swabbing method (based on *Indoor Dust Sampling Protocols*, Attachment 4A in US EPA document *Proposed Sampling Program to Determine Extent of World Trade Center Impacts to the Indoor Environment*, June 2005) is outlined below:

1) First swabbing, side-to-side: Hold one edge of the swab between the thumb and forefinger, draping the wipe over the fingers of a gloved hand. Hold fingers together, hand flat, and swab the selected surface area, starting at either corner furthest away from the operator, using a slow side to side sweeping motion. During swabbing, apply pressure to the fingertips. At the end of the first pass from one side to the other, turn the leading edge of the swab (the portion of the swab touching the surface) 180 degrees, pulling the swab path slightly down or closer to the operator make a second side-to-side pass in the reverse direction, slightly overlapping the first pass. Continue to cover the sampling area within the template, using the slightly overlapping side-to-side passes with the 180 degree turns at each edge until the close/bottom corner of the template is reached. Carefully lift the leading dust line into the swab using a slight rolling motion of the hand to capture the dust inside the swab. Fold the swab in half with the sample side folded inside the fold.

2) Second swabbing, top-to-bottom: using a clean side of the swab, perform a second swabbing over the sampling area within the template starting from a far/top corner in the same manner used for the first swabbing, except use a top-to-bottom sweeping of the surface. When the close/bottom corner of the template is reached, carefully lift the leading dust line into the swab using a slight rolling motion of the hand to capture the dust inside the swab. Fold the swab in half (again) with the sample from this second swabbing folded inside the fold.

3) Third swabbing, clean corners: using a clean side of the swab, perform a third swabbing around the perimeter of the sampling area within the template to pick up any dust remaining in the corners. Start from one edge of the template and use the same swabbing technique as described above. When the perimeter has been swabbed and the starting location reached, carefully lift the leading dust line into the swab. Fold the swab in half one more time with the sample from this third swabbing folded inside the fold.

- The swab should be transferred into a clean laboratory sample jar for analysis.

Swabbing of windowsills should be done according to the swabbing method above but masking tape should be used to mark out an outline of the swabbing location if the 10cm x 10 cm template does not fit on the windowsill.

When an interior swab sample is collected, the following information should be collected as recommended in *AS 4874-2000*:

- *Location of the premises where sample was collected;*
- *Time and date of sample collection;*
- *Name and address of organization performing the sampling;*
- *Name of Project Manager;*
- *Name of person taking the sample;*
- *Justification for selection and precise location of each sampling point;*
- *Nature of the surfaces sampled;*
- *Type of sample collection method employed (wipe or vacuum), including full details of the equipment;*
- *Dimensions of area sampled;*
- *Where results are to be expressed on a mass concentration basis, the mass of the sample collected;*
- *Observations unique to the sampling point(s), that may affect interpretation of the results, including the presence of paint flakes;*
- *Recent history of the areas sampled, with particular respect to whether cleaning has taken place; and*
- *A reference to this Australian Standard (i.e. AS 4874).*

It is also recommended that, during sample collection, the relevant guideline that the sample should be compared against based on the sample location (accessibility by children) is noted by the sampler. This will assist in tabulating the data once analytical results are available.

7.5.6 Review of Analytical Results

As the outcome of the “Type A” sampling is not known at the time of writing the *SAP,* Golder has developed a series of possible outcomes and recommended responses to these outcomes. Results of the soil, rainwater and swab analysis will vary depending on how lead and nickel have been deposited within the Esperance area. The following sections indicate the outcomes that may occur from soil, rainwater and interior swab sampling and the recommended responses to be initiated following that outcome.

- **Outcome 1** – If the concentrations of lead and nickel in the composite soil sample analysed by XRF are higher than 60 mg/kg and 120 mg/kg, respectively (see Section 7.5.1), the individual sub-samples must be analysed to assess whether a hotspot that exceeds regulatory guidelines exists at the sampling location. If a soil sub-sample result and/or the rainwater and/or interior swab results are above recommended DOH clean up guidelines (Section 5.0) then go to “Type B” sampling within a 20 m radius of the sampling point with results above the clean up guidelines. Furthermore, review results of the “Type A” sampling to assess whether contours of contamination are discernable[2]. If contours are discernable, then these areas would also progress to “Type B” sampling.

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[2] Golder suggests that sample results are plotted on a map and visually assessed to observe whether some areas have greater concentrations of lead and/or nickel compared to other areas. Concentrations that are not related to distance from the Port may be associated with meteorological or topographical factors such as wind or depressed areas where contaminants may have accumulated, or a localised source of lead and/or nickel independent of emissions from the Port.

- **Outcome 2** – If soil sub-samples results, rainwater and interior swab results are below recommended DOH clean up guidelines, or if composite soil samples are below 20% of guideline levels, then review sampling results to assess whether contours of elevated soil concentrations are discernable. If contours are discernable, then these areas would progress to “Type B” sampling. If contours are not discernable (i.e. results appear random), then identify sample locations in which the lead and nickel concentrations are in the highest 10th percentile of the distribution and undertake “Type B” sampling within 20 m of each location.

- **Outcome 3 -** In addition to the selection of “Type B” sampling locations based on the potential outcomes of “Type A” sampling discussed above, Golder also recommends “Type B” sampling is undertaken according to the following:

  - “Type B” sampling is undertaken at locations in Esperance where historical data collected by regulatory authorities (DEC, DOH etc) including rainwater, plant, dust, soil and human blood exceeds the relevant health-based criteria and guidelines for lead and/or nickel.

A flowchart (Figure B) has been provided to assist in which course of action to take based on “Type A” sample results.

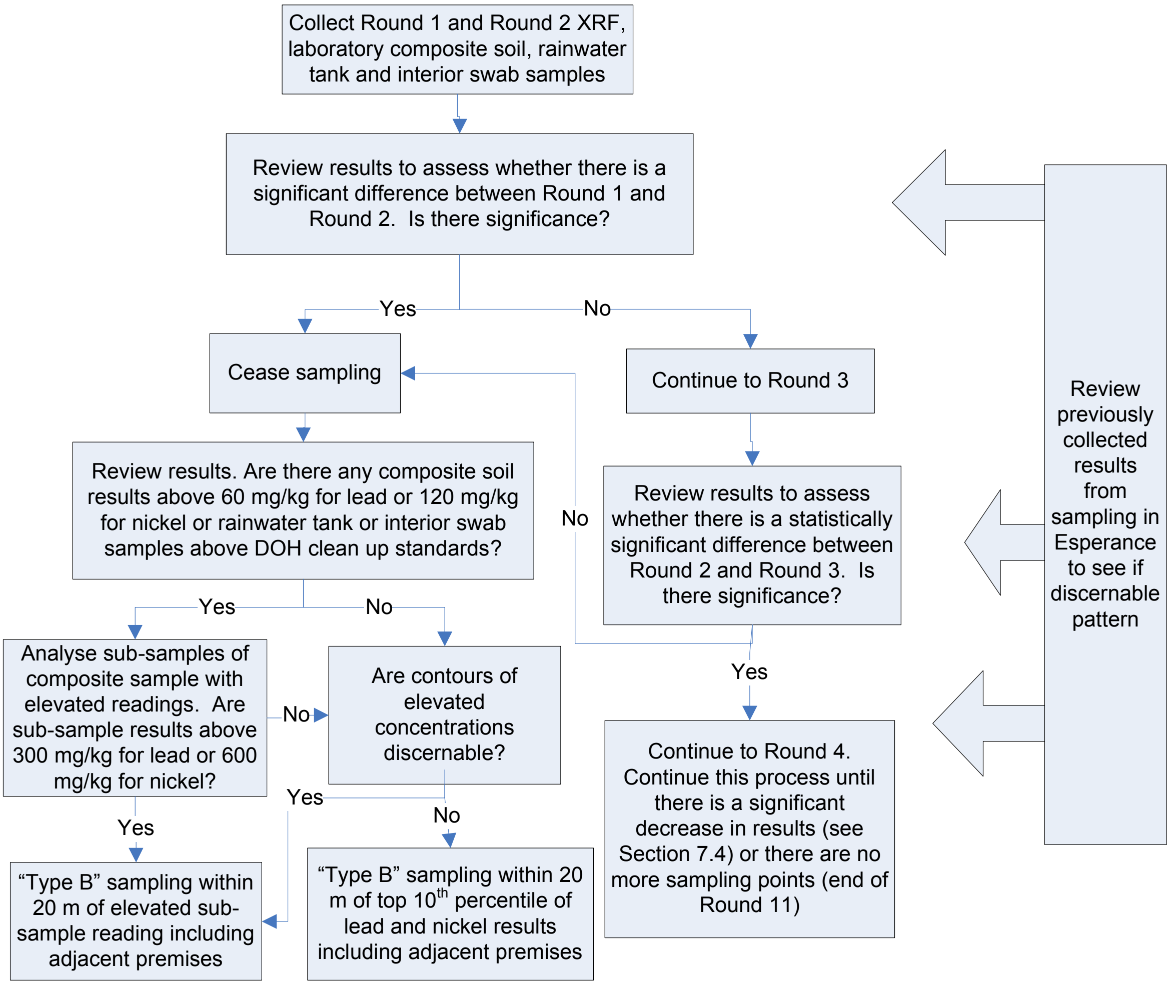

Figure B: Flowchart Showing Steps Taken Following "Type A" Sample Collection

8.0 TASK 3 - "TYPE B" SAMPLING DESIGN

For "Type B" sampling the RFQ requested advice on "*the most appropriate method of refining the area of contamination to more accurately assess the delineation of contaminated and non contaminated areas and hence identify the premises which will or will not require Type C sampling*".

The outcome of "Task A" sampling and review of data previously collected by regulatory authorities is anticipated to provide a discernable pattern of the extent of contamination of the Esperance townsite with lead and nickel. The objective of "Type B" sampling is to refine the identified pattern of contamination or elevated concentrations as assessed by "Type A" sampling. More intensive sampling of areas where elevated concentrations of lead and/or nickel have been identified can do this.

At the time of writing this document, "Type A" sampling had not been undertaken. The areas of elevated lead and/or nickel concentrations identified in "Type A" sampling may be limited and the SC may choose to bypass "Type B" sampling and move to "Type C" sampling, if they deem this appropriate.

8.1 Sampling Strategy

The area(s) selected for "Type B" sampling may be based on the results of "Type A" sampling, distance from the Port, meteorological factors, topographical factors, other factors not yet known or a combination of these factors.

Figure B shows the decision pathway recommended by Golder for assessing whether “Type B” sampling is undertaken depending on possible outcomes of “Type A” sampling.

8.2 Sampling Methodology

The following sections outline the sampling methodology recommended for “Type B” sampling.

8.2.1 Residents Survey

In this initial step, information is gathered from discussions with the residential and commercial property (premises) owners/occupiers regarding their site and its use and observations from a site walkover.

The discussion with the owner about the site may include the following:

- Number, age, gender and occupation of occupants;
- Nature of premises;
- Location of each premises with respect to major roads and motorised traffic;
- Cleaning patterns e.g. vacuum cleaning patterns, type of vacuum, frequency of use, bag replacement frequency, dusting, wiping;
- Premises ownership (owned / rented);
- Pet behaviour patterns (internal / external);
- Activities on the premises that may contribute to high lead levels (i.e. lead sinker production, leadlight hobbies, winemaking, pottery glazing);
- Age of premises; and
- Age of floor coverings / furnishings.

Visual observations will be an important part of the *SAP*, as the age and construction features of each property will be an important factor in the intrusion of dust into the premises. These would include the following:

- Premises construction material, i.e. evidence of renovation, ceiling / roof condition, paint condition, potential lead paint sources around the premises, other potential lead sources around the premises;
- Important characteristics of living / working areas, i.e. presence of fireplace, window types, ventilation / drafts, types of floor coverings;
- Presence of roof space; and
- Observations of the ceiling structure, i.e. presence of conduits from the ceiling to the interior of the premises, dust levels.

Appendix B contains a proposed questionnaire that will assist in gathering this information.

8.2.2 Composite Soil Sampling and Drip Zone Samples

The US EPA document *Superfund Lead-contaminated Residential Sites Handbook* (US EPA, 2003) provides guidance on sampling of residential properties to assess lead contamination. The following soil sampling methodology is based on US EPA (2003) and DEC guidance on sampling and analysis plans (DEP, 2001).

It is recommended that composite soil samples are collected from yard areas according to the general layout of each yard. Composite samples should comprise four sub-samples collected from the front yard, back yard and the side yard (if substantial). Sub-samples should be equally spaced within the respective area of the yard and be outside the drip zone of the roof and away from the influences of any painted surfaces. Four discrete drip-zone soil samples should also be collected for XRF analysis. Figure C, Figure D and Figure E are modified from US EPA (2003) and provide guidance on the location of sub-samples and drip zone samples according to the layout of the yard.

The location of sub-samples may include the following areas:

- Driveways (if unpaved);
- Garden beds;
- Any unsealed yard areas where rainwater tanks have been emptied (if applicable); and
- Children's play areas if separate from front yards/back yards.

A sample of roof gutter 'sludge' (if applicable) may also be collected into soil sample jars for laboratory analysis.

The following information as provided in *AS4874-2000* should be noted for each sample collected to assist with the discussion of results:

- *Material of which adjacent buildings are constructed and the age of the buildings;*
- *Renovation activities being conducted on adjacent buildings;*
- *Distance from roads;*
- *Distance from commercial garages;*
- *Distance from mining and smelting operations (past and present);*
- *Dustfall rates and suspended particles;*
- *Prevailing winds immediately prior to sampling; and*
- *Underlying mineralisation.*

If these points are not relevant or the information is not readily accessible (i.e. dustfall rates in a particular area), this should be noted on the field form or chain of custody documentation.

QA/QC procedures outlined in Section 11.0 should be applied during "Type B" sampling. Notes regarding the sample location, soil type, depth of sample (top 3 cm recommended), photograph and GPS coordinates for each sub-sample and drip zone sample should be recorded.

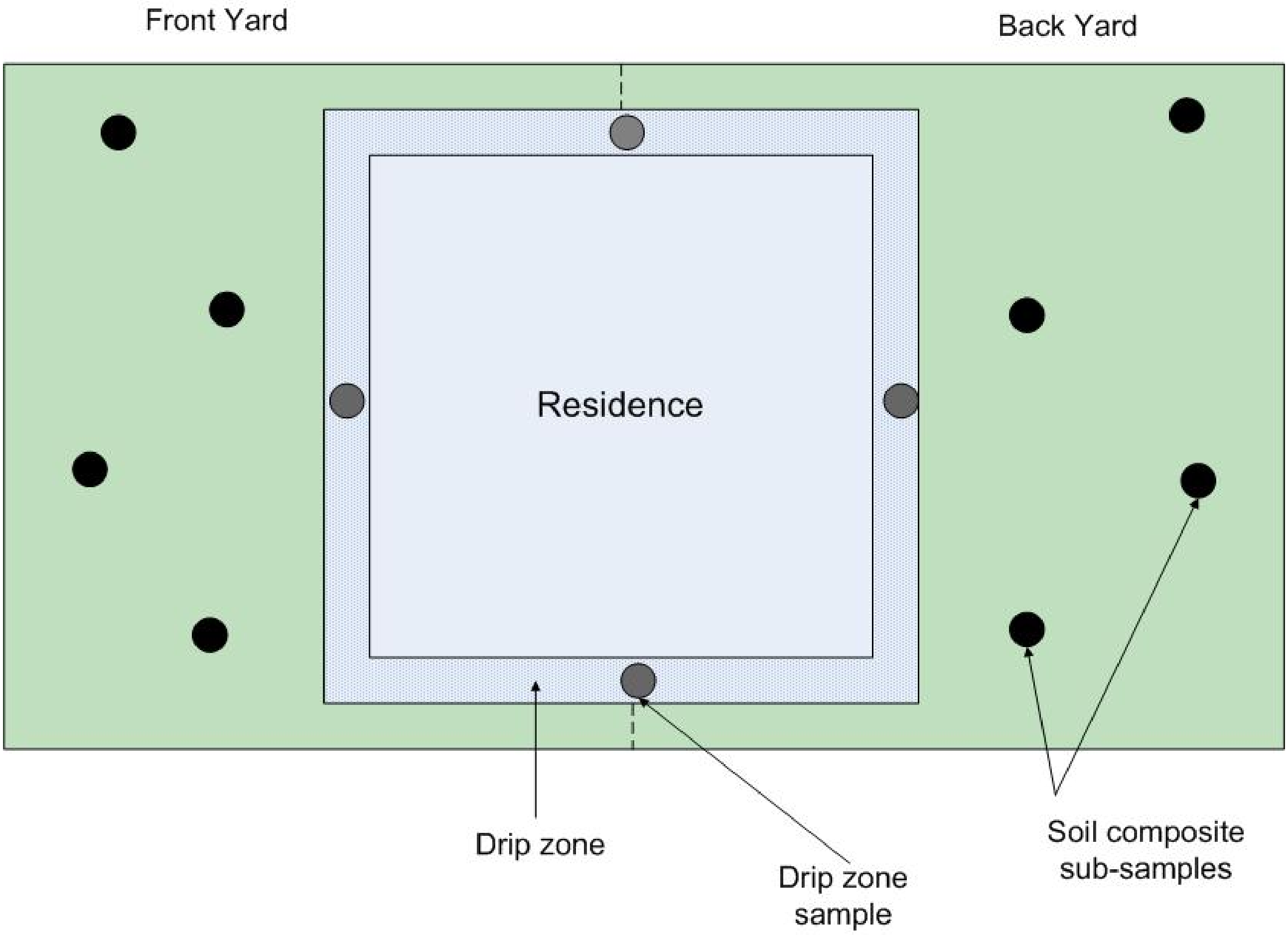

Figure C: Composite soil and drip zone sampling in premises with small side yard

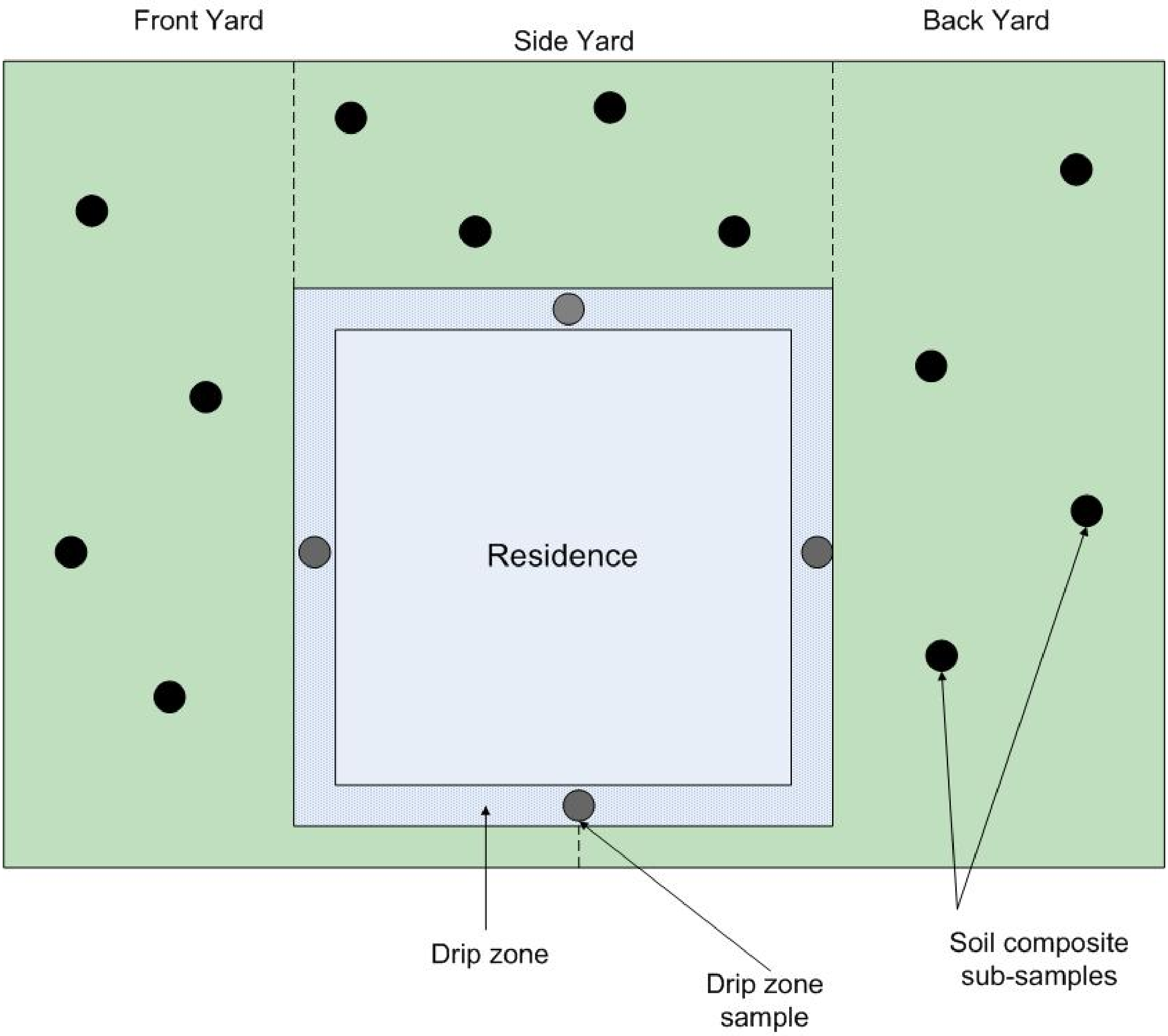

Figure D: Composite soil and drip zone sampling in premises with substantial side yard

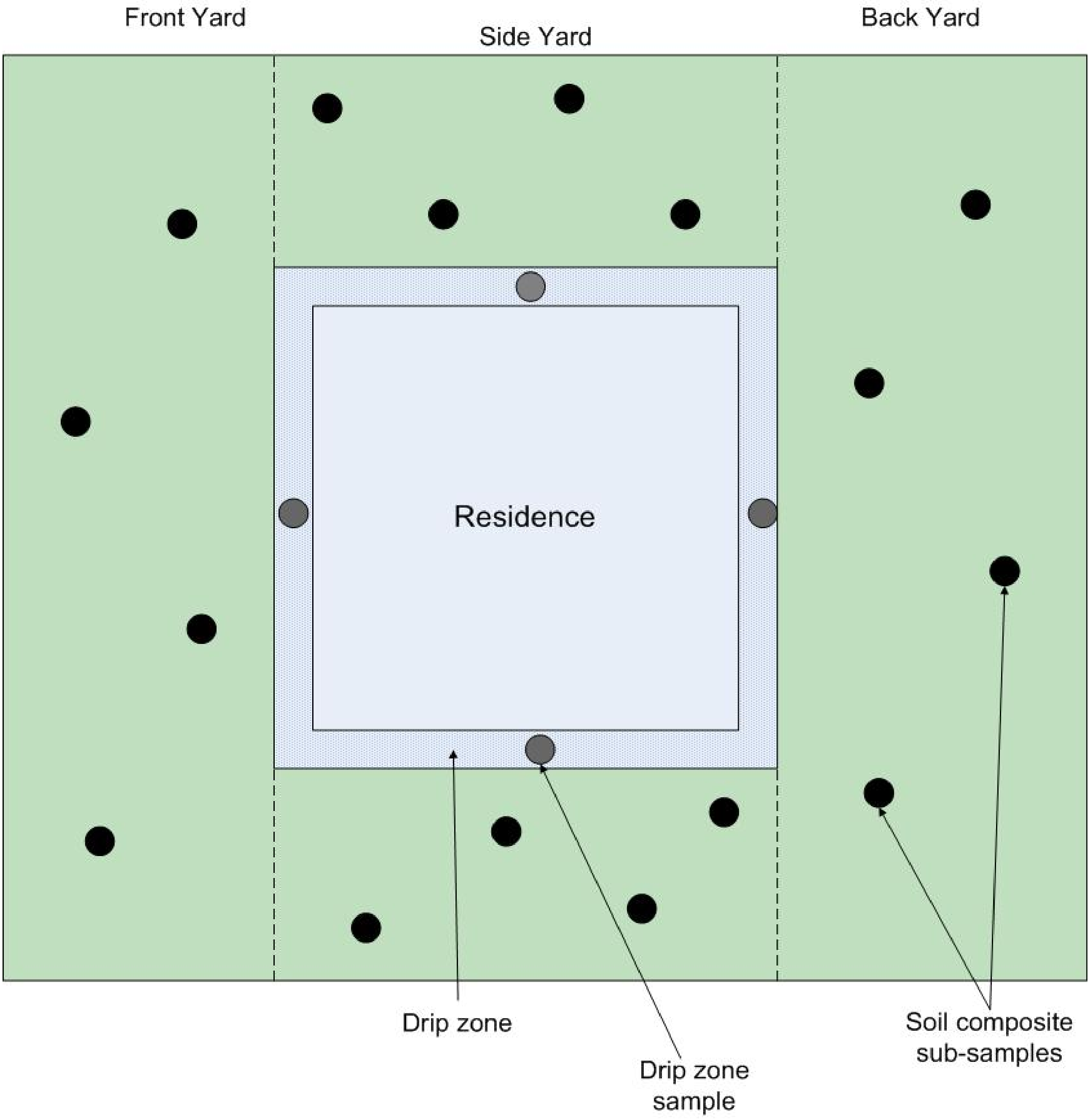

Figure E: Composite soil and drip zone sampling for premises with yards greater than 465 m^2

8.2.3 XRF Sampling

XRF sampling of soil samples taken during “Type B” sampling should be done according to the methodology summarised in Section 7.5.2.

8.2.4 Rainwater sampling

Rainwater sampling from rainwater tanks on premises selected for “Type B” sampling should be done according to the methodology summarised in Section 7.5.4 and QA/QC procedures in Section 11.0.

8.2.5 Judgemental Interior Swab Sampling

Judgemental interior swab sampling within premises selected for “Type B” sampling should be done according to the methodology summarised in Section 7.5.5 and QA/QC procedures in Section 11.0.

8.2.6 Laboratory Analysis

Laboratory analysis of soil samples taken during “Type B” sampling should be done according to the recommendations outlined in Section 7.5.3.

8.3 Review of Analytical Results

Results from both “Type A” and “Type B” sampling should be reviewed and compared to the DOH adopted clean-up guideline levels for lead and nickel or analysed for discernable distribution patterns to assess whether “Type C” sampling is recommended at each premises.

9.0 TASK 4 - “TYPE C” SAMPLING DESIGN

The objective of the “Type C” sampling design as requested in the RFQ is to “*develop the procedures and protocols for the internal and external assessment of homes and other premises*” in Esperance for contamination with lead and/or nickel. Transport requested that “Type C” sampling include the following:

- *inside surfaces – especially those accessible to young children such as floors and window ledges. Samples should also be taken of more difficult to reach/access surfaces which are accessible to adults;*
- *carpets – samples should be taken from deep within the carpet pile;*
- *outside surfaces – these include paving, outdoor furniture, children’s cubby houses, window ledges etc;*
- *soils including soils at the bottom of downpipes, garden beds etc;*
- *rainwater;*
- *roof gutter sludge;*
- *roof surfaces; and*
- *ceiling voids (roof cavities).*

Golder has not included soil sampling in “Type C” sampling as soil will be sampled as part of “Type A” and “Type B” sampling and further sampling is considered unlikely to supply additional information on lead and nickel contamination.

9.1 Sampling Strategy

Golder recommends that premises are scheduled for “Type C” sampling following analysis of the results of “Type A” and “Type B” sampling.

9.2 Sampling Methodology

The sampling methodology for “Type C” sampling incorporates sampling of media inside and outside premises and includes rainwater and dust.

9.2.1 Rainwater Tanks

Rainwater tank(s) present at a premises selected for “Type C” sampling should be sampled if they have not previously been sampled in “Type A” or “Type B” sampling.

Rainwater sampling from rainwater tanks on premises selected for “Type C” sampling should be done according to the methodology summarised in Section 7.5.4 and QA/QC procedures in Section 11.0.

9.2.2 Dust

Each premises sampled should include standardised and judgmental sampling locations for the collection of dust. Standardised locations would provide points of comparison between sites. Judgmental sampling locations would provide a representation of the households’ potential exposure, i.e. high use areas, painted surfaces, areas of ingress particular to the household and other site-specific locations.

Surface wipe sampling and vacuum sampling are proposed.

Information that should be noted for each dust sample collected is outlined in Section 7.5.5.

9.2.2.1 Surface Swab Samples

Judgemental swab sampling of internal and external surfaces is recommended where the sampler deems it appropriate.

The following standard set of internal surface swab locations are recommended at each premises and are based on guidance in *AS 4874-2000*:

- Fridge top;
- Windowsill[3] in most used room beneath a window that opens;
- Window-well in most used room (from same window);
- Kitchen bench / work area (high use / cleaning);
- Kitchen bench / work area (infrequent use / cleaning – e.g. back corner of bench);
- Floors;
- Surfaces under vents;
- Childs play area surface, interior (if applicable); and
- Top of filing cabinet or similar storage cabinet for commercial premises.

The following standard set of external surface swab locations are recommended at each premises:

- Windowsill of a window facing the Port;
- Outdoor furniture;
- Paving;
- Children’s cubby house (if applicable); and
- Sheds/garages (if applicable).

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[3] Swabbing of windowsills should be done according to the swabbing method above but masking tape should be used to mark out an outline of the swabbing location if the 10cm x 10 cm template does not fit on the windowsill

AS 4874-2000 recommends sampling of external deposited dust using either vacuum sampling or collection by brushing. Concerns were raised by ECRP (ECRP, 2009) regarding re-suspension of particles during dry brushing, so, as an alternative, surface wipe sampling or vacuum sampling could be performed as described in *AS4874-2000, Sections 3.6.2.3 and 3.6.1.3,* respectively*.* Golder recommends the sampler make a decision on the most appropriate sampling method of these external surfaces at the time of sampling. The chosen method of collection should be thoroughly documented (including method type and the dimensions of the sample location) during the sampling program along with information outlined in Section 7.5.5.

9.2.2.2 Vacuum Samples

Golder proposes that vacuum sampling in standardised locations inside premises be carried out using an industrial-type bagless vacuum cleaner fitted with a high efficiency particulate air (HEPA) filter. Sampling and analysis of the contents of the vacuum cleaner provides a bulk qualitative dataset relating to overall contamination of floor surfaces. One bulk sample from the vacuum cleaner particulate receptacle will be collected from each premises during the sampling process. This type of sample integrates dust collected from vacuumed areas.

The following sampling locations are recommended for the bulk sample:

- Principal entrance to premises (within the first 1 m);
- Hallways;
- Beneath windows that open;
- Children’s bedrooms and/or play areas; and
- Floor surface of most utilised room.

It is recommended that an approximately 1 m by 1 m floor area is selected in the room and the location recorded. If the floor surface consists of rugs, it is recommended that the rug that is used the most is selected. After marking the area with tape the surface can be vacuumed by the sampler in 25 cm strips, making four passes back and forth on each strip.

Following sampling, the vacuum cleaner collection receptacle should be opened and the entire sample removed by a gloved hand and placed into a sample bag. The sample bag should be sealed immediately and labelled with the location details. QA and QC procedures as outlined in Section 11.0 should be implemented as applicable. Fibres and/or pet hairs should be taken from the ‘dust’ component of the bag and placed in a separate bag, which should be retained for at least 12 months.

Vacuum sampling of exterior surfaces such as paving may be done if swab sampling is deemed inappropriate by the sampler for that surface at the time of sampling (see Section 9.2.2.1).

9.2.2.3 External Roof Surfaces

It is recommended that a minimum of two samples are taken from external roof surfaces. Golder has been unable to locate Australian or international guidelines on the sampling of dust from external roof surfaces. Golder recommends the use of the swab sampling methodology outlined in Section 9.2.2.1 for external roof surfaces.

Unless already taken during “Type B” sampling, “sludge” from roof gutters may be collected using a gloved hand and placed into soil sample jars for subsequent laboratory analysis for lead and nickel concentrations.

9.2.3 Ceiling Voids

It is recommended that ceiling dust is collected using a clean dustpan and brush from inside the ceiling void of the premises approximately 1 m inside a manhole cover. The size of the sample area should be decided at the time of sampling and kept constant through the sampling process. The ECRP raised concern regarding the re-suspension of particles using the dry brush method (ECRP, 2009), therefore vacuum sampling may be appropriate. Information regarding the equipment that should be used and the appropriate sample collection techniques are provided in Section 9.2.2.2. The dry brush sampling method was recommended since the decontamination process associated with the dry brush sampling method is less cumbersome than that associated with vacuum sampling.

A tarpaulin or similar may be used underneath the manhole to prevent introduction of dust into the premises. If a tarpaulin is used, it must be discarded after use and a new tarpaulin used for each premises.

9.3 Review of Analytical Results

Results of “Type C” sampling should be compared to the clean-up guidelines recommended by the DOH (Table 1). The SC should use professional judgement when reviewing results from sampling media for which clean-up guidelines have not been established e.g. roof surfaces and depositional dust.

10.0 TASK 5 - TYPE “D” SAMPLING DESIGN

The objective of “Type D” sampling is to provide analytical data that the SC can use to assess whether or not the cleaning of premises in Esperance after “Type C” sampling was satisfactory. “Type D” sampling is effectively validation sampling following cleaning to assess whether cleaning was adequate by comparing results to cleanup guidelines (Section 5.0). Premises selected for “Type D” sampling should include only those premises for which “Type C” sampling and subsequent cleaning was done.

Golder assumes that the clean-up methodologies have been validated to achieve the degree of clean-up required to meet guidelines.

10.1 Sampling Strategy

The sampling strategy recommended by Golder for “Type D” sampling to validate the effectiveness of the clean-up programme is to sample near the areas sampled for “Type C” sampling using the same techniques. “Type D” sampling should only be carried out at locations where clean-up was undertaken, e.g. if only internal surfaces were cleaned, then only the internal surfaces should be assessed by “Type D” sampling. Preferably, “Type D” samples should be taken as close as possible to the “Type B” and “Type C” sample location.

10.2 Sampling Methodology

The sampling methodologies recommended for “Type D” sampling are the same as those recommended for “Type C” sampling (see Section 9.2) and “Type B” sampling (see Section 8.2). Soil, rainwater and/or dust samples may be taken.

10.2.1 Depositional Dust

The SC may wish to consider including depositional dust samplers in several locations within premises selected for “Type D” sampling, to allow measurement of contaminant loading over a defined time. The following outlines a method for depositional dust sampling.

The internal depositional dust samplers that have been recommended by the CCWA are Petri dishes. This method is described by Gulson *et al.* (1995) as comprising the following elements:

- Prior to use, the polycarbonate Petri dishes (50 and 85 mm in diameter) are soaked overnight in an alkaline detergent, rinsed with deionised water, soaked overnight in 6 M HCl, rinsed with clean water and air-dried in a laminar flow workbench station.

- The Petri dishes are secured to the sampling location with a piece of ‘Blutak’ (plasticine) on the exterior base of the dish.

- Spatial variation is assessed with the dishes being placed in two separate locations (e.g. different rooms) at heights varying from floor level to 2 m for periods ranging from 3 to 6 months.

- To assess reproducibility, two Petri dishes can be placed side-by-side.
- To remove the dust, the Petri dish is approximately half-filled with 7 M HNO_3, and the solution decanted by rinsing into an acid-cleaned Teflon beaker.
- The following locations are recommended for the Petri dish samples:
  - Entry / Exit approximately 1 metre from ground level (this may require a stool or similar structure on which to site the sampler).
  - Window sill in the most used room.
  - Top of fridge or kitchen cupboard.
  - Top of bookcase or similar.
  - Two covered areas outside of the home (e.g., patio and covered car park area).

The dust samplers should not be obstructed from dust fall. The ChemCentre has indicated that in their experience, monthly sample collection for indoor dusts is not feasible due to the low masses of dust normally collected and has recommended 3 monthly collection of samples.

10.3 Review of Analytical Results

Results of “Type D” sampling should be compared to the clean-up guidelines recommended by the DOH (Table 1) as well as the results of “Type B” and “Type C” sampling.

11.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

QA/QC is integral to developing a sampling programme that accurately reflects levels of a contaminant in the environment that is being assessed. The following QA/QC sections provide guidance for the implementation of field and laboratory procedures to reduce cross-contamination and provide information that will assist in assessing whether the analytical results are robust and accurate.

11.1 Field

Samples should be collected according to the relevant Australian Standards and the principles set out in DEC guidance (DEP, 2001). QA/QC procedures include the following:

- Clean powder free gloves are to be used when sampling to prevent cross-contamination. A fresh pair of unused gloves must be used for each sample collected.
- Field duplicate samples (field duplicate, for analysis at the primary laboratory) and field triplicate samples (laboratory duplicates, for analysis at the secondary laboratory) are to be collected at the rate of 1 in 20 (5% duplicate, 5% triplicate).
- Field blanks, trip blanks, container blanks are to be collected as necessary.
- Each sample taken should be given a unique sample identification number that should be included on chain-of-custody documentation.
- Samples are to be stored in an esky containing ice bricks and submitted along with chain-of-custody documentation to the laboratory.
- Once the samples have been collected and labelled, should be received by the laboratory as soon as practicable to facilitate prompt results and to meet holding times.
- Chain-of-custody forms must be used and must include elements such as the sample location, date samples collected and analysis to be undertaken (see Section 11.2).

- Sampling implements (if used), such as a shovel or trowel, must be decontaminated using Decon 90 solution and a de-ionised water rinse between sampling locations. A rinsate blank must be collected for each piece of equipment for each day of sampling (e.g. if using two shovels for five days, 10 rinsate samples must be taken, one per shovel per day for five days). Further information is available in *AS 4482.1-2005* regarding sampling collection methods and suitable decontamination procedures.

For XRF sampling, the following field QA/QC procedures are recommended:

- Calibration checks of the XRF should be performed as per manufacturer's recommendations to verify calibration and to evaluate the limits of detection.
- The use of instrument blanks and method blanks should be undertaken as per manufacturer's recommendations.
- A precision measurement should be undertaken once per day as described by US EPA (2007).

Criteria that are adopted by Golder for assessing QA/QC data are contained in applicable Australian Standards and guidelines for sampling methodologies and duplicate ratios (e.g. *AS 4482.1-2005* and *AS/NZS 5667.1:1998*).

11.2 Chain-of-custody Documentation

Chain-of-custody documentation should be used for every sample collected for analysis and should include the following (where applicable):

- Investigator contact person;
- Laboratory contact person;
- Date and time of sample collection;
- Sample identification number;
- Container type;
- Sample matrix;
- Analysis requested;
- Preservation;
- Sampler's name and signature;
- Name and signature of person relinquishing samples, with date and time; and
- Name and signature of person receiving samples, with date and time.

11.3 Relative Percent Difference

The Relative Percent Difference (RPD) used by Golder to evaluate the variability between a primary sample and its corresponding duplicate sample is calculated according to the following formula:

$$\%RPD = \left|\frac{A - B}{A + B}\right| \text{ x } 200$$

Where: A is the concentration of the primary laboratory analyte, and

B is the corresponding duplicate result.

In calculating RPD values, the following protocols are adopted by Golder:

- Where both concentrations are below laboratory limit of reporting (LOR), no RPD is to be calculated.
- Where one laboratory concentration is below the LOR and one is above, a value of one half of the detection limit is to be substituted for the non-detect sample.
- Where both concentrations are above LOR, the RPD is to be calculated as per the formula above.

Based on the *Australian Standard (AS 4482.1-2005)*, Golder considers that RPD values of less than 50% are satisfactory for soil analyses. RPD values of more than 50% may be satisfactory for low concentrations near the detection limit.

RPD values of 50% are deemed satisfactory by Golder if both sample concentrations are between 1 to 10 times the LOR. If sample concentrations are higher than 10 times the LOR and either or both of the samples exceed established reference values, then the highest sample concentration is reported by Golder and the samples may be reanalysed.

11.4 Laboratory

Laboratory spikes, laboratory duplicates, etc, are conducted by NATA accredited laboratories to evaluate whether laboratory procedures are being suitably conducted and results are accurate and precise.

The particulars of QA/QC for laboratories may differ depending on the analysis being undertaken. The RPD is generally considered by Golder to be satisfactory if below 50%. In Golder’s experience, laboratory blanks are generally run at the beginning and end of each batch of samples. Spike recovery analyses for each analytical suite, for each batch of samples received (i.e. one spike recovery analyses for every 10 samples) is also usually undertaken. Spike recovery analysis results within a range of 75% to 125% are considered by Golder to be satisfactory for QA purposes. Due to laboratory techniques, some analytes will consistently have low recoveries and these would be considered on a case-by-case basis.

11.5 Data Management

Laboratory results should be reviewed within five working days of receipt from the laboratory. The quality control report provided by the laboratory can then be checked so that issues which may exist with the data are investigated prior to undertaking data interpretation. An assessment of the RPDs of both laboratory and field duplicates is advised. It is recommended that the data is stored in an electronic format as well as produced in hard copy, and the hard copies are stored along with chain of custody forms in the project file.

11.6 Uncertainty

Sampling with an XRF brings uncertainty regarding whether measurements of lead and nickel are accurate. It is imperative that QA/QC guidelines associated with the XRF are followed and confirmatory laboratory samples are collected, analysed and compared to XRF samples to check the precision and accuracy of the XRF throughout the sampling programme.

This *SAP* does not consider areas along the rail line outside of the sampling area that may have been affected by the Port’s operations. Golder suggests that, if a clear contour of contamination is noted along the rail line within the sampling area, then “Type B” sampling be performed to further assess those areas that are outside of the sampling area.

There is little information regarding background levels of lead or nickel in soil and rainwater tank water in Australia, therefore, it is difficult to assess levels of lead and nickel below reference values.

This *SAP* suggests surface sampling of soils and water from rainwater tanks within Esperance in line with the source being from Port operations. This *SAP* does not address lead and/or nickel contamination at depth.

If levels of lead and/or nickel exceeding guideline concentrations are encountered during the sampling programme, it can not be directly linked to the Port’s operations, as there may be other sources of lead and nickel in the environment related to these results. For instance, the use of leaded petrol and the use of lead-based paints may contribute to higher concentrations of lead. Understanding background concentrations in an environment can assist when considering elevated concentrations of lead and nickel. Review of the Albany data was performed (Section 6.0) but was not considered satisfactory for this *SAP.*

As part of this *SAP*, Golder has recommended review of data previously collected in Esperance by regulatory authorities. Due to the confidential nature of this information, Transport will require permission to access these data and should seek advice from the DEC and DOH regarding this.

11.7 Health and Safety Considerations

SAP include considerations for the health and safety of the sampling personnel, as well as of the environment. This includes consideration of the various hazards that might be encountered (e.g. chemical, physical, and biological) for which a safety plan is recommended. Golder recommends that Transport require their sampling personnel to have a health and safety plan in place before undertaking the fieldwork.

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Report Signature Page

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Legend

● Suggested Sampling Location

Street

Proposed Sampling Distance From Port (m)

🟦	500
🟦	1000
🟦	1500
⬜	2000
⬜	2500
⬜	3000
⬜	3500
🟨	4000
🟨	4500
🟨	5000
🟨	5500

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Imagery sourced from Landgate,
Shared Land Information Portal (SLIP)
2007 Esperance, extracted July 2009.
Roads, StreetPro V9, 2009

0 250 500 1,000
Metres

A3 SCALE 1:30,000

Datum GDA94, Projection MGA Zone 51

CLIENT DEPARTMENT OF TRANSPORT
PROJECT 097643268 001 R REV1
DATE 28/07/2009
COMPILED JOR
APPROVED SAT

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Department of Transport
Sampling Analysis Plan

PROPOSED SAMPLING POINTS FOR "TYPE A" SAMPLING

FIGURE 1

APPENDIX A

DEC Guideline: Sampling and Analysis Plans

DEVELOPMENT OF SAMPLING AND ANALYSIS PROGRAMS

5

MANAGEMENT SERIES

Contaminated Sites Management Series

Development of Sampling and Analysis Programs

(*Guideline for the Assessment of Sites Incorporating Underground Storage Tanks* and
Contaminated Site Assessment Guidelines for the Development of Sampling and
***Analysis Programs* as amended)**

December 2001

Department of **Environmental Protection**
Government of **Western Australia**

PREFACE

This guideline for the *Development of Sampling and Analysis Programs* includes the former draft *Guidelines for the Assessment of Sites Incorporating Underground Storage Tanks* (DEP, 2000) and former draft *Contaminated Site Assessment Guidelines for the Development of Sampling and Analysis Programs* (DEP, 2000) and has been prepared by the Department of Environmental Protection (DEP) to provide consultants, local government authorities, industry and other interested parties in the assessment of contaminated sites in Western Australia (WA).

This guideline provides an indication of the methods and work required when developing a sampling and analysis program (SAP) for the investigation and validation of sites including those incorporating underground storage tanks (USTs). The guideline entitled *Reporting on Site Assessments* (DEP, 2001) provides details, including a checklist of information required by the DEP when reporting on site investigations and remediation validations.

Enquiries about this guideline may be directed to the Contaminated Sites Section as follows:

Contaminated Sites Section
Environmental Regulation Division
Department of Environmental Protection
PO Box K822
PERTH WA 6842
Telephone: (08) 9222 7000
Fax: (08) 9322 1598

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The DEP acknowledges the following organisations for assistance in the preparation of this guideline:

- CSIRO Land and Water;
- Water and Rivers Commission (WRC);
- WorkSafe WA;
- EnviroSkill International Pty Ltd;
- PPK Environment and Infrastructure Pty Ltd; and
- URS Australia Pty Ltd.

LIMITATIONS

This guideline applies to persons investigating contaminated sites. The contents herein provide guidance only and do not purport to provide a methodology for the assessment of sites. Competent professionals should be engaged to provide specific advice in relation to the assessment of contaminated sites.

This guideline should be used in conjunction with the texts referenced herein, and any other appropriate references.

This guideline does not contain occupational safety and health procedures and should therefore not be used as a field manual for sampling. WorkSafe Western Australia should be consulted regarding such requirements.

DISCLAIMER

This guideline has been prepared by the DEP in good faith exercising all due care and attention. No representation or warranty, expressed or implied, is made as to the relevance, accuracy, completeness or fitness for purposes of this document in respect of any particular user's circumstances. Users of this guideline should satisfy themselves concerning its application to their situation, and where necessary seek expert advice.

CONTAMINATED SITES MANAGEMENT SERIES

This guideline forms part of the Contaminated Sites Management Series developed by the DEP to address certain key aspects of contaminated site management in Western Australia.

The management series contains the following guidelines:

- Assessment Levels for Soil, Sediment and Water;
- Certificate of Contamination Audit Scheme;
- Community Consultation;
- Contaminated Site Auditor Accreditation Scheme;
- Development of Sampling and Analysis Programs;
- Disclosure Statements;
- Guidance for Planners;
- Potentially Contaminating Activities, Industries, and Landuses;
- Reporting of Known or Suspected Contaminated Sites;
- Reporting on Site Assessments; and
- Site Classification Scheme.

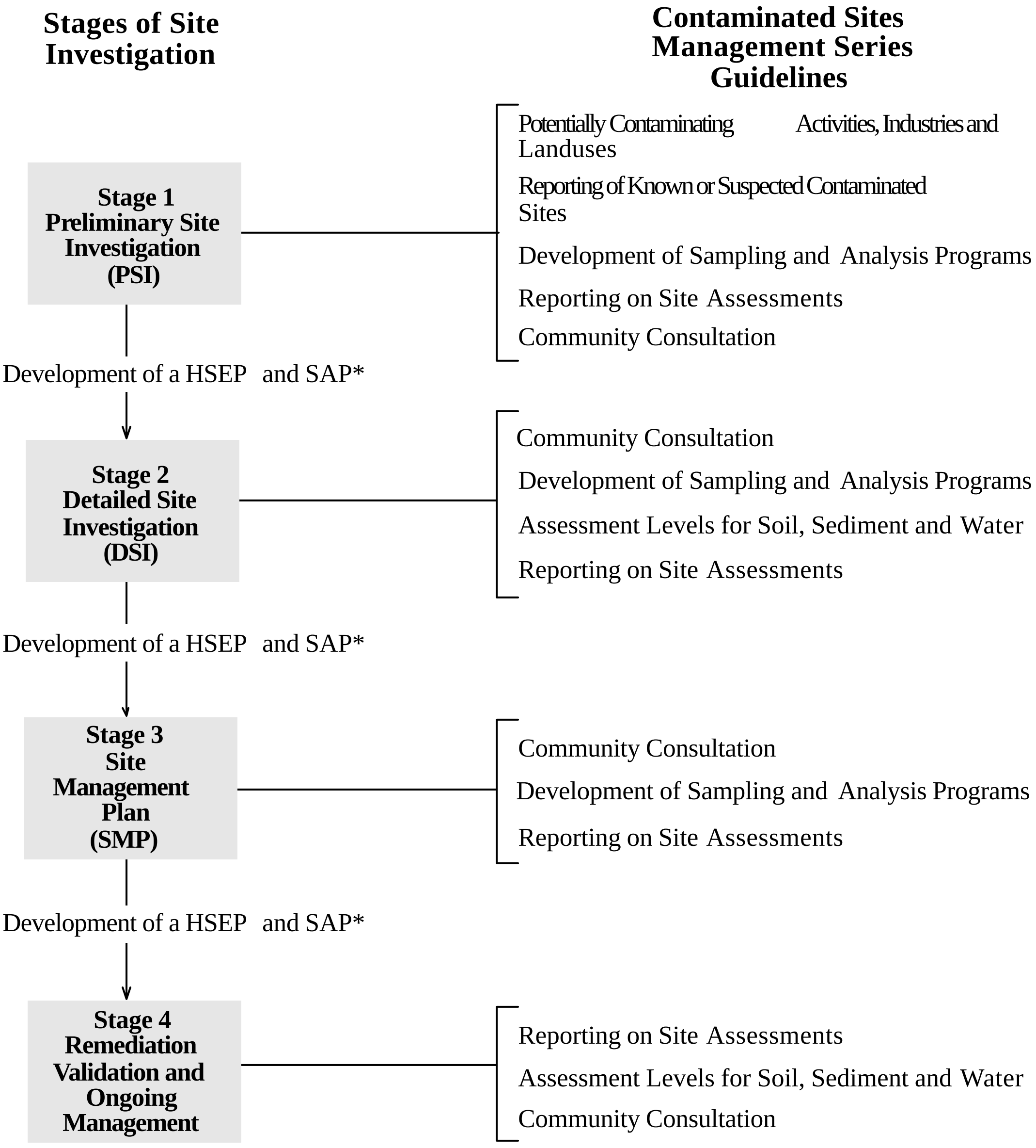
Reference to this guideline should ensure that the general requirements of the DEP are satisfied.

Copies of these guidelines are available on the DEP website, www.environ.wa.gov.au

STAGED APPROACH TO SITE INVESTIGATIONS

The Contaminated Sites Management Series of guidelines has been developed by the DEP to encourage a consistent approach to contaminated site assessment and management. One of the main focuses of the series is the **staged approach to site investigation**.

The purpose of this flow-chart is to highlight to the reader the appropriate reference guideline(s) during each of the stages of site investigation.



*Where samples are to be collected a Health, Safety and Environment Plan (HSEP), and Sampling and Analysis Program (SAP) should be prepared.

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1. INTRODUCTION

Summary

- **The objective of this guideline is to assist practitioners to develop sampling and analysis programs (SAP) as part of the contamination assessment, remediation and validation stages of site assessments.**
- **A SAP is a site-specific document which presents:**
  - **the objective(s) for sampling at a contaminated site;**
  - **a methodology for determining sampling, sample preservation, sample transportation, sample storage, quality assurance and quality control (QA/QC), and analysis; and**
  - **the number, type and locations for sampling to ensure the collection of representative, reproducible data on the nature and extent of *in situ* contamination.**

The development of a SAP is a key factor in conducting a site investigation or remediation program to ensure that representative and reproducible data is obtained, which can be used to assess the nature and extent of *in situ* contamination and any risks posed to the environment and human health.

Prior to the collection of samples at a site, during a Preliminary Site Investigation (PSI), Detailed Site Investigation (DSI) or Remediation Validation, a comprehensive SAP should be developed. Page III presents a flow chart indicating when SAPs and Health and Safety and Environment Plans (HSEPs) should be developed in the site assessment process.

The level of detail within a SAP is determined by both the characteristics of the site and the objectives of the program. There can be no prescribed method for the assessment of site contamination as each site presents a different scenario in terms of contaminants, exposure pathways and desired end uses. The assessment of a contaminated or potentially contaminated site should therefore be undertaken on a site-specific basis.

As such, this guideline is not prescriptive, but presents factors that should be taken into account when developing a SAP. This guideline should be used in conjunction with any other relevant guidelines, standards and information sources as well as professional experience and judgement to develop the most appropriate program for a site. Full justification for the location of sampling points, frequency and analytes used, should be provided in the SAP and any subsequent reports.

The development of a SAP ensures that all persons collecting samples at a site are aware of the objectives of the sampling program, the correct sampling methodologies, sample preservation and analytical program, etc. This information is important as it will provide guidance where field conditions differ from expected conditions, and to ensure reliability of sampling.

Reference to this guideline should ensure that the general requirements of the DEP are satisfied. Specialist advice should be sought on site-specific requirements from competent professionals and the DEP, where appropriate.

1.1 GOAL

The goal of this guideline is to provide practical guidance to assist practitioners in developing a SAP to:

- obtain representative and reproducible data of the nature and extent of *in situ* contamination at a site in order to adequately assess the risk and potential risk that a site poses to both human health and the environment; and
- validate remediation of a site to ensure that no contamination remains on-site which may pose a risk to human health or the environment.

1.2 SCOPE

This guideline has been prepared specifically to assist practitioners to develop a SAP for assessing contaminated sites.

This guideline presents the requirements for the development of a SAP for soil, sediment and groundwater. For each of these media, factors to be considered in determining the sampling design, including the location (spatial and vertical), number and frequency of sampling are provided. This guideline also addresses QA/QC.

This guideline does not cover:

- sampling methodologies and techniques;
- sampling requirements for biota or food chains;
- remediation methodologies and techniques; or
- occupational health and safety issues.

Where information on contaminant concentrations in plant and animal tissues is required, reference should be made to the risk assessment methodologies provided in the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) (NEPC, 1999).

This guideline provides factors that should be considered in developing a SAP. The guideline for *Reporting on Site Assessments* (DEP, 2001) should be referenced for a general overview of the stages of site assessment, and the requirements of the DEP with respect to reporting on site assessments.

The *Potentially Contaminating Activities, Industries and Landuses* (DEP, 2001) guideline provides a list of potentially contaminating activities that can be used to assess the possibility for contamination at a site.

Additional information with respect to contamination assessment levels can be obtained from the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline.

1.3 HEALTH & SAFETY

The scope of <u>this guideline does not cover the health and safety aspects of contaminated sites</u>, however some points have been included here to prompt the consideration of health and safety when planning activities on contaminated sites.

Health and Safety Plans (HSEPs) should be considered before each sampling stage.

The *Occupational Safety and Health Act 1984* places a clear obligation on a person to ensure the safety and health of anyone they engage to do work (such as drillers, earthmoving contractors and consultants). It is therefore recommended that HSEPs be produced and the contents adequately communicated to all site personnel prior to their exposure to the site.

Guidance on the contents of HSEPs can be obtained from the *National Environment Protection (Assessment of Site Contamination) Measure (Schedule B(9) Protection of Health and the Environment During the Assessment of Site Contamination)* (NEPC, 1999).

Copies of HSEPs should be forwarded to WorkSafe Western Australia along with notification of any site works prior to the commencement of the site works. WorkSafe Western Australia should be contacted for further information on notification of site works and HSEP requirements.

Any risks to the public such as adjacent landowners/occupants should be identified and measures implemented to minimise them.

It is expected that when conducting site investigations:

- practitioners engage contractors (e.g. drillers, earth moving contractors, surveyors) who have undergone some training associated with operating on contaminated sites, and ensure that all persons on the site are familiar with the relevant health and safety aspects of the site;
- drilling contractors holding an appropriate National Water Well Drillers Licence would be engaged where groundwater bores are to be installed; and
- competent professionals possessing the relevant skills, knowledge, experience and judgement would supervise all intrusive investigations, e.g. geologist, hydrogeologist.

If the site subject to the investigation is on a mine-site as defined under the *Mine Safety and Inspection Act 1994*, then a copy of the HSEP should be submitted to the Department of Mineral and Petroleum Resources (DMPR).

1.4 STAGED APPROACH TO SITE INVESTIGATIONS

In order to obtain the most representative samples and data on a site, a staged approach to contaminated site assessment should be adopted, for example:

- **Stage 1** - Preliminary Site Investigation (PSI);
- **Stage 2** - Detailed Site Investigation (DSI);
- **Stage 3** - Site Management Plan (SMP); and
- **Stage 4** - Remediation, Validation and Ongoing Management.

Reports can be submitted to the DEP for review at any stage of the assessment process or on completion of the entire investigation. The DEP recommends, however, that a staged approach to the submission of contaminated site reports be taken, consistent with the staged approach to site investigations as outlined in the *Reporting on Site Assessments* (DEP, 2001). Submitting reports in a staged manner enables the DEP to provide guidance and advice in the early stages of the investigation, which often reduces delays during the final assessment and clearance of sites. Difficulties associated with the quality of information, sampling parameters and distribution, adopted investigation levels and environmentally sensitive issues can be resolved in the early stages of the investigation. Submission of reports on completion of each of the stages of investigation also enables site investigation and management objectives to be developed in consultation with the DEP prior to commencement of the next stage of investigation. The DEP is not, however to be used as a consultant. Suitable reports should therefore be developed to meet the requirements as outlined in this guideline.

Preliminary Site Investigations (PSIs) identify the site characteristics (location, layout, building construction, hydrogeology) and historical landuses and activities at the site. PSIs are primarily "desk top" studies, although a detailed site inspection (including interviews with site representatives) should be included where possible. PSIs may include the collection of preliminary samples. The findings of a PSI form the basis of all further site investigations, and therefore it is imperative that as much information on the site as possible is obtained and included in this preliminary phase of investigation.

Following a PSI, Detailed Site Investigations (DSIs) may be required to confirm the findings of the PSI, to identify any additional evidence of contamination via sampling and to determine the impact that contamination at a site has, or may have, on human health and the environment.

The purpose of a DSI is to conduct detailed sampling to establish the nature of contamination, the lateral and vertical distribution of contaminants, determine contaminant concentrations, clarify contamination sources and give consideration to potential human health and environmental impacts. DSIs may be completed in a number of stages depending upon the size or complexity of the site.

The development of a Site Management Plan (SMP) involves the selection of an effective management strategy which is practical, achieves the desired outcomes and is socially and environmentally acceptable. The SMP should address:

- specific data gaps identified during the DSI;
- identify the additional information required for the selection and/or design of remedial and/or management options (e.g. active remediation, risk mitigation); and
- identify the required baseline data for sites subject to monitored natural attenuation (passive remediation).

Remediation, validation and ongoing management enable the success of the remediation to be assessed. The remediation and validation report should clearly demonstrate that the land is suitable for its current or intended use, that the beneficial use of environmental receptors including groundwater or surface water is not compromised and that all the objectives of the remediation have been achieved and accounted for.

1.5 RELEVANT REFERENCES

A large amount of literature is available on the assessment of contaminated sites. This guideline has been written to amalgamate the key points of a number of references, but it is by no means exhaustive and more detailed information should be obtained on specific media, contaminants etc. where required prior to design of a program. Some useful references are provided in Section 9.

2. SAMPLING AND ANALYSIS PROGRAM DESIGN

Summary

- **Sampling and analysis programs (SAP) should be developed prior to the collection of any samples on a site.**
- **SAPs should be site-specific.**
- **SAPs should be based upon the findings of PSIs. (Where sampling is to be conducted as part of the PSI, then a SAP should be developed based upon the findings of the desktop study and detailed site inspection conducted as part of the PSI).**
- **The SAP should document, as a minimum:**
  - **the objectives of the sampling program;**
  - **background information on the site (location, activities, known contaminants);**
  - **the number and type of samples to be collected;**
  - **sample collection locations (sample patterns);**
  - **a description of sampling methods including sample containers, sampling devices and equipment, equipment decontamination procedures, sample handling procedures, sample preservation methods and reference to recognised protocols;**
  - **disposal of sampling/remedial waste (soils, sediment, waters, decontamination wastes, etc.);**
  - **sample analysis requirements (analytes and analytical methods); and**
  - **QA/QC methods.**

2.1 INTRODUCTION

Prior to the collection of any samples at a site, a SAP should be developed to determine the most effective and representative sampling strategies and analysis parameters.

A SAP should document, as a minimum:

- the objectives of the sampling program;
- background information on the site (e.g. location, activities, known contaminants);
- the number and type of samples to be collected;
- sample collection (sample patterns);
- a description of sampling methods (including sample containers, sampling devices and equipment, equipment decontamination procedures, sample handling procedures and reference to recognised protocols, etc.), sample collection information (e.g. depth, methodology), sample identification, preservation, handling and storage details and chain of custody details;
- disposal of sampling/remedial waste (soil, sediment, waters, decontamination wastes, etc.);
- sample analysis requirements; and
- QA/QC methods.

The development of a SAP should take into consideration the following:

- findings of the PSI;
- objective(s) of the SAP;
- contaminant distribution (known or inferred, point source or diffuse source, handling of contaminated material to avoid spreading the contamination, and prevention of further distribution);

- background sampling locations (to benchmark site contamination and establish any naturally elevated parameters);
- choice of analytes;
- health and safety of site workers, general public and the environment (preparation of a HSEP);
- potential site outcomes (proposed site uses);
- most effective sampling techniques; and
- proposed disposal location for any excavated/abstracted waste during/following sampling and remedial works.

2.2 OBJECTIVES OF SAMPLING AND DATA COLLECTION

Prior to designing a SAP, the objectives of the program should be defined. A SAP can range in detail from a preliminary sample screening exercise to a plan for a DSI, or form part of remediation, validation and ongoing management. The objectives of the program must be clearly defined to enable determination of the most appropriate sample types, sampling locations, analysis parameters, analytical detection limits and review of investigation findings to determine if the objectives have been met.

The objectives of a SAP can include:

- determination of the location of contaminant sources;
- determination of the nature, magnitude and extent of contamination;
- determination of background concentrations;
- determination of contaminant migration and exposure pathways;
- data quality objectives (DQOs) (statements which specify the quality of the data required, guidance can be sought in *AS 4482.1 – 1997 Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 1: Non-volatile and Semi-Volatile Compounds* (*AS4482.1-1997*));
- provision of meaningful and accurate results on which to base human health and/or ecological risk assessments; and
- provision of validation data to determine successful remediation of a site.

Once determined, the objective(s) of the program will influence:

- what information is required;
- what level of detail of information is required;
- sample methodologies (including the number and type of samples to be collected and sample locations);
- sample preservation requirements; and
- analysis parameters.

During investigation of contaminated sites, the objectives of a SAP may change as more contamination is identified, new sources of contamination are identified, or redevelopment plans for the site change, etc. If the objectives of the project change, then it is important to re-assess the SAP and determine if it will still provide the required information/results.

Documentation of the required works in a SAP, or recording all actions and decisions, allows review of how an investigator has structured the program of sampling and analysis. It also enables comparisons to be made of works planned against the actual field activities and sampling completed in order to identify whether the objectives of the program were adopted during the course of the investigation.

2.3 SAMPLING REQUIREMENTS

In order to adequately assess a contaminated site, a SAP should be designed to include the number and type of samples, and locations of sample collection. Table 1 presents a summary of the sampling requirements for the assessment of contamination at a site and validation of remediation.

Where a UST(s) is, or has been present at a site, reference should be made to Appendix F for the minimum sampling requirements in the vicinity of the tank and any associated infrastructure.

Sampling of groundwater is required unless it can be demonstrated to the satisfaction of the DEP that there is limited potential for groundwater to be contaminated at the site.

More detailed information is presented within the relevant sections of this guideline.

TABLE 1. OVERVIEW OF SAMPLING REQUIREMENTS

	ASSESSMENT OF CONTAMINATION		**VALIDATION OF REMEDIATION**	
	No. of Samples	**Sample Location**	**No. of Samples**	**Sample Location**
Soil	Dependent upon size of site, geology, hydrogeology, type of contamination, historical landuse, outcomes of previous investigations, etc.	Laterally and vertically spaced to determine the extent of contamination.	Dependent upon extent of contamination and remedial works.	Systematic, evenly spaced samples across walls and bottom of all excavated areas. Sampling in areas of remaining contamination in addition to the grid pattern.
Sediment	Dependent upon the size of the site, the sediment lithology, the type of contamination, historical landuse, outcomes of previous investigations, etc.	Laterally and vertically spaced to determine the extent of contamination.	Dependent upon extent of contamination and remedial works.	Grid pattern across dredge area, and along boundaries of dredge area. Monitoring to ensure that the source is removed, and build up of contaminated sediments does not re-occur.
Groundwater	Dependent upon the size of the site, aquifer properties (including permeability, groundwater levels, presence of confining units/sand lenses, etc.) and groundwater quality.	Within, down-gradient and up-gradient of groundwater contamination plume. Minimum of three bores to allow estimation of groundwater flow direction.	Dependent upon aquifer properties and temporal variations in water quality and levels. Consecutive results should show contaminant concentrations below acceptable guideline criteria.	Dependent upon location of groundwater monitoring bore locations across site.

2.4 CHOICE OF ANALYTES

The choice of analytes for sample analysis should be site-specific and take into consideration:

- the objectives of the program;
- known contamination (e.g. historical leaks and spillages);
- potential contamination sources (identified during the PSI and site inspection);
- proposed landuse for the site;

- potentially applicable comparison levels or guidelines;
- availability of National Association of Testing Authorities (NATA) accredited laboratories to undertake analysis; and
- breakdown products of contaminants (in some cases these can be more toxic, and/or more mobile than the parent contaminant (e.g. TCE)).

The *Potentially Contaminating Activities, Industries and Landuses* (DEP, 2001) guideline provides a list of potential contaminants (analytes) which may be associated with some activities, industries and landuses, and can be used as a general guide when selecting analytes. However site-specific information obtained during a PSI should identify the actual and potential contaminants at a site, based on site activities.

When determining analytes, the detection limits should be considered. The required detection limits may vary based upon the level of contamination at a site and the landuse/beneficial use of the site. Detection limits should be below the relevant assessment levels. Consultation with the laboratory during the development of the SAP maybe required to determine what can be achieved.

Where soils are being assessed, in addition to the type and concentration of contaminants present, determination of the leachability of those contaminants may also be required where groundwater is at a shallow depth, or where disposal to landfill is to occur.

There is a range of testing procedures to assess the leachability of contaminants. In the past, the USEPA Toxicity Characteristic Leaching Procedures (TCLP) has been used but this has now been superseded by the leaching procedures defined in *AS 4439.1-1999 Wastes, Sediments and Contaminated Soils – Preparation of Leachates – Preliminary Assessment* (*AS 4439.1*) (ASLP). Justification for the use of the leachability testing procedure should be provided and used on a case-specific basis.

Where sediments are being assessed, it is recommended that the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000) be referred to in determining the most suitable analytes and analytical methods. Where sediments are being sampled, the quality of pore water within the sediments should be considered, which is also a source of contamination. The ecological impacts of contaminated sediments are influenced by the bioavailability of the contaminants of concern. Therefore when assessing sediments, the total concentrations of contamination, dilute acid-solubility of contaminants, organic content, grain size and speciation of the sediments and pore water concentrations should be considered. Refer to other sections of this guideline for further information about sediment sampling.

Analysis of samples should be completed by laboratories that hold NATA accreditation for the particular analytes and methodologies required. It should be noted that a laboratory may be NATA accredited for some analytes and not others, and therefore a check of the laboratory accreditation for the required analysis should be made prior to consigning the samples.

Laboratory certificates should be NATA endorsed reports.

Schedule B(3) Guideline on Laboratory Analysis of Potentially Contaminated Soils, National Environment Protection (Assessment of Site Contamination) Measure (NEPC, 1999) refers to various laboratory techniques for the analysis of contaminated soils.

2.5 APPROPRIATE SAMPLING METHODS

2.5.1 Factors to be Considered

This guideline does not contain information on sampling techniques or methodologies. Information on sampling techniques can be sourced from other references. However, in selecting the most appropriate sampling method, the following factors should be considered:

- knowledge and experience of field staff in sampling techniques;
- accessibility to the site and/or sections of the site;
- availability of equipment;
- nature of contaminant(s);
- health and safety of site personnel and general public (e.g. exposure to contaminants, potential release of contaminants);
- anticipated extent of contamination (e.g. hand augers can be used to sample shallow contamination in soft soils, whereas deeper contamination and hard soils may require a drilling rig);
- geological conditions (e.g. type of drilling rig required);
- hydrogeological conditions (e.g. depth to watertable, aquifer type, number of aquifers, groundwater flow direction);
- potential for vertical and/or lateral cross contamination during and after the collection of samples;
- sensitivity of samples to potential cross-contamination and degradation in storage;
- type and volume of wastes produced and waste disposal methods;
- disturbance of flora/fauna/heritage sites; and
- potential for release of contamination to the wider environment and surrounding beneficial uses (e.g. dust, odours, and stormwater runoff).

All samples should be collected using appropriate techniques to provide representative and reproducible data.

It should be noted that where underground structures (USTs, pipe-work, bowsers, drainage lines, etc.) remain *in situ* during any investigations, the results are indicative only. In order to determine a more detailed and accurate representation of contamination, collection of samples from beneath infrastructure is required and this is generally not possible where underground infrastructure remains, and particularly where the site remains operational, as access is often limited. Therefore any information obtained from sites where infrastructure remains will require validation following decommissioning of the site.

Where the location of a UST and associated infrastructure is unknown, the use of geophysical methods and field-testing should also be considered.

2.5.2 Composite Sampling

A composite sample is made up of a number of constituent samples (sub-samples), which are collected from a body of material and combined into a single sample, which therefore represents the average conditions of the body of material.

The rationale behind the use of composite sampling is often to reduce analytical costs, and to provide a general indication of the presence/absence of contamination in investigation programs. Although in principle composite samples represent the average concentration of the constituent samples, a major drawback with compositing is that a constituent sample containing a high concentration of contaminant can remain undetected because its concentration was diluted in the compositing process. Conversely, constituent samples may contain lower concentrations than the average, and where the average is above assessment levels, may result in investigation/remediation of areas that are below the assessment levels. Therefore, when interpreting data from composite samples, it is extremely important to be aware that as the data only shows an average concentration, there are likely to be higher or lower concentrations *in situ.*

With this in mind, composite sampling can be used as an initial screening tool only. More detailed information on the exact extent of contamination can only be obtained from individual (or discreet) samples.

In addition, due to the fact that composite samples do not provide an indication of the possible maximum contaminant concentrations, the results from composite sampling cannot be used for health or ecological risk assessments.

Based on the above limitations, composite sampling can be used for PSIs, however the DEP will not accept composite sample results as final results of an investigation unless adequate justification of the use of composites is provided, as well as full delineation of any identified contamination. Compositing for validation purposes is not accepted by the DEP.

Where composite sampling is to be used at a site, the following should be considered:

- all samples are made up from the same number of constituent samples;
- no more than 4 constituent samples should be included in a composite sample;
- constituent samples should be equal in size;
- constituent samples should be obtained from immediately adjacent sampling points;
- constituent samples should only be composited laterally, not vertically;
- constituent samples should be obtained from locations which are evenly spaced;
- composite samples should be composited in a laboratory environment and not in the field. Composites prepared outside the laboratory would be unlikely to provide acceptable results because of the difficulties in controlling homogenising and weighing of samples Compositing in the laboratory should be undertaken in accordance with *AS 4482.1-1997*; and
- composite samples are not satisfactory for semi-volatile and volatile substances e.g. Total Petroleum Hydrocarbons (TPH) and Polycyclic Aromatic Hydrocarbons (PAH).

Where composite samples are to be collected, information on compositing methodology should be detailed and should also be reported in any documents relating to the sampling.

Where composite sampling is undertaken, adjustment of the assessment level is required. Further information on adjusting assessment levels for composite sampling can be obtained from the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline.

2.5.2.1 Soil

In addition to the limitations discussed above, composite sampling of soils is unsuitable for:

- site validation sampling, as it does not provide a definitive indication of concentrations remaining within the soil; and
- soils with a high clay content, as mixing and compositing is difficult.

2.5.2.2 Sediment

As with soils, compositing of sediment samples is not recommended unless more detailed investigations are to be completed. It is recommended that compositing of sediments only occur over small areas of a site otherwise too much information may be lost regarding the nature and distribution of the contamination.

Composite samples should not be made from sediments of a different nature/geology (e.g. organic content/particle size). The nature of the sediment bed should always be visually checked first to ensure that the sediment beds are geologically compatible.

The correct sampling and analytical methodologies for each of the known or expected contaminants should be identified and incorporated into the SAP.

Further information may be obtained from *AS/NZS 5667.12:1999 Water Quality – Sampling, Part 12: Guidance on Sampling of Bottom Sediments* (*AS/NZS 5667.12:1999*).

2.5.2.3 Groundwater

Compositing of groundwater samples, say from a number of monitoring bores at a site, is not accepted due to the limitations of compositing including the:

- inherent variability in groundwater conditions;
- possibility of cross contamination from compositing equipment; and
- possibility of alteration of sample by ambient conditions during compositing e.g. temperature, oxidation, ultra-violet radiation, introduction of dust, etc.

2.6 SAMPLE IDENTIFICATION, PRESERVATION, TRANSPORTATION AND STORAGE

2.6.1 Sample Identification

The SAP should document the sample identification requirements for all types of samples to be collected at the site. Sample identification should be completed as outlined in *AS/NZS 5667.1:1998 Water Quality – Sampling, Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples* (*AS/NZS 5667.1:1998*).

2.7 SAMPLE PRESERVATION, TRANSPORTATION AND STORAGE

The SAP should document the sample preservation, transportation and storage requirements of all types of samples to be collected at the site. These parameters are dependent upon the sample media and choice of analytes. Sample preservation, transportation and storage should be completed according to relevant Australian Standards such as *AS 4482.1-1997* and *AS 4482.2-1999 Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 2: Volatile Substances* (*AS 4482.2*) and *AS/NZS 5667.1:1998* and the analytical methods selected.

It is recommended that sample preservation, transportation and storage requirements be confirmed with the analytical laboratory prior to sample collection.

2.8 UNCERTAINTY OF SAMPLING

In all sampling programs there will be uncertainty as to how representative samples are of *in situ* contamination. This is due to a number of factors, including cross contamination of samples, spatial and temporal variations in soil, sediments and groundwater, and the fact that most contamination is present beneath the ground surface and is therefore unidentified until intrusive investigations are conducted (and even then generally only small areas of the subsurface). A SAP should be designed so as to minimise uncertainty by basing it on a sound understanding of the site and the contaminants of concern.

Sampling uncertainty should be taken into consideration where decisions are being made based on analysis results, where statistical sampling methods of site assessment are applied and where modelling is based on analysis results.

2.9 SAMPLING AND REMEDIAL WASTE DISPOSAL

Where site contamination is known, or where it is determined that there is a high probability of contamination, it is recommended that remediation options (for example, disposal) of any material during sampling and remediation activities (soil/sediment/water) be addressed prior to commencing site works so as to:

- minimise health and safety risks to the public, site personnel and the environment associated with exposure to any contaminated material;
- determine a strategy/method for characterising the waste;
- determine the packaging requirements for waste material to be disposed of so as to reduce the risk of costly and unsafe double handling (refer to the *Australian Dangerous Goods Code* Volume 1 and 2);
- minimise time taken to obtain the appropriate approvals for off-site disposal; and
- determine whether a permit for the transport of contaminated soils or liquid waste is required under the *Environmental Protection (Controlled Waste) Regulations 2001*.

Where the concentration of contaminants in the spoil is below the relevant investigation levels as documented in the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline or DEP approved site-specific criteria, waste may be disposed of on-site at a suitable location following approval from the site operator/owner and any interested parties and authorities.

Where the spoil is contaminated above the relevant assessment or site-specific levels for the current or proposed landuse of the site, treatment (on-site or off-site), or off-site disposal to a suitable location is required.

There are certain requirements for the transport of soils that are classified as a Controlled Waste as per the *Environmental Protection (Controlled Waste) Regulations 2001*. The collection or transport of controlled waste must be carried out by a licensed transporter as stipulated under Regulation 15 of the *Environmental Protection (Controlled Waste) Regulations 2001*. A licensed transporter is defined as a person who collects and transports a controlled waste for financial reward or more than the notifiable quantity (one tonne in the case of contaminated soil) of controlled waste in a period of one year.

An occupier of premises who wishes to remove a controlled waste from the premises must apply to the Chief Executive Officer of the DEP for a permit to remove the waste.

Disposal of contaminated soil to landfill must be at a licensed waste disposal facility and undertaken in accordance with the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001).

3. QUALITY ASSURANCE/QUALITY CONTROL

The SAP should include measures to ensure the quality and reproducibility of all sampling methods used at the site. Accurate QA/QC is required to ensure that the samples collected are of the highest quality and integrity, and that analysis is completed with the highest accuracy. Where results are produced with inadequate QA/QC procedures, they cannot be accepted as being accurate or representative of the site conditions. This guideline does not contain details on QA/QC measures as these are covered in *AS 4482.1-1997* and *AS/NZS 5667.1:1998*. Guidance on the QA/QC reporting requirements of the DEP for contaminated site management is provided in the *Reporting on Site Assessments* (DEP, 2001) guideline.

QA/QC measures are required regardless of the number of samples taken.

3.1 FIELD QUALITY ASSURANCE/QUALITY CONTROL

The minimum field QA/QC procedures that should be performed are:

- collection of quality control samples (for sampling and transportation/preservation methods);
- use of standardised field sampling forms and methods; and
- documenting calibration and use of field instruments.

Field QC samples are used to check for:

- processes that may have interfered with the integrity of the samples;
- cross contamination in the sampling procedures;
- cross contamination from bore construction/sampling infrastructure installation;
- interferences from preservatives added to the samples;
- interferences from processes within the analytical laboratory;
- accuracy of the laboratory results; and
- precision of the laboratory results.

3.1.1 Quality Control Samples

The objectives of the SAP should be considered when determining appropriate QC procedures.

AS 4482.1-1997 provides further information on quality control samples which should be included when collecting soil samples, these should also be adopted when sampling sediments. *AS/NZS 5667.1:1998* provides information on the collection of quality control samples when sampling waters. Refer to Table 2 for a summary of some of the quality control samples that need to be considered for soil, sediment and groundwater sampling.

TABLE 2. QUALITY CONTROL SAMPLES

Type of Sample	Why are they used?	How many should be taken?	Field/Laboratory considerations
Background samples[1]	Background samples are generally taken outside of the boundary of the site. They provide a comparison of environmental quality away from the influence of the site.	Dependent upon the nature of contamination and background environment.	-
Blind replicate samples (also known as field duplicates)[1]	Blind replicates may be used to identify the variation in analyte concentration between samples collected from the same sampling point and/or also the repeatability of the laboratory's analysis.	One blind replicate sample should be taken for every 20 investigative samples.	The blind replicate sample and investigative sample from the sample location should be submitted to the laboratory as two individual samples without any indication to the laboratory that they have been duplicated.
Split samples[1]	Split samples are used to provide a check on the analytical proficiency of the laboratories.	For every 20 samples, one set of split samples should be taken.	One sample from each set should be submitted to a different laboratory for analysis. The same analytes should be determined by both laboratories, using the same analytical methods.
Rinsate blanks[1]	Rinsate blanks are used to provide confirmation that there has been no cross-contamination of substances from the sampling equipment used. They are collected where cross-contamination of samples is likely to impact on the validity of the sampling and assessment process.	Dependent upon types of equipment used, contaminants and decontamination procedures.	-
Field blank[2]	Field blanks are used to estimate contamination of a sample during the collection procedure.	At least one field blank should be taken per sampling team per trip per collection apparatus.	-
Transport blank[2]	Transport blanks are used to estimate the amount of contamination introduced during the transport and storage of samples from the time of sampling until the time of analysis.	At least one transport blank should be collected per group of samples.	-
Container blanks[2]	Container blanks estimate contamination from the container and preservation technique during storage of the sample.	At least one container blank should be collected per group of samples.	A cleaned sample container is filled with water of an appropriate quality, any preservative used in the sample is added, and then the blank is stored for the same time and same location as the samples for analysis.
Other QC samples[1]	-	Dependent upon sampling and preservation techniques.	-

Notes:

1. please refer to *AS 4482.1-1997* for further information.
2. please refer to *AS/NZS 5667.1:1998* for further information.

3.2 LABORATORY QUALITY ASSURANCE/QUALITY CONTROL

Analysis of samples should be completed by laboratories that hold NATA accreditation for the particular parameters and methodologies required. Information on QA/QC methods should be obtained from the designated laboratory prior to sampling to ensure that they meet the requirements of the SAP.

The laboratory report should be a NATA endorsed report and include:

- the results of the analysis;
- sample numbers;
- laboratory numbers;
- a statement about the condition of the samples when they were received (e.g. on ice, cold, ambient, etc.);
- date and time of receipt;
- dates and times of extraction and analysis of samples;
- quality control results; and
- a report on sampling and extraction holding times.

3.3 CHAIN OF CUSTODY

Chain of custody is the process that details the links in the transfer of samples between the time of collection and their arrival at the designated laboratory. Several transfers may take place in this process, for instance, from the sampler to the courier, and from the courier to the laboratory.

The minimum information that should be included on the Chain of Custody form is as follows (refer to *AS 4482.1-1997* for further information):

- name of person transferring the samples;
- name of person receiving samples (e.g. laboratory staff);
- time and date the samples were taken;
- time and date the samples are received (e.g. at the laboratory);
- condition of samples (e.g. chilled or ambient temperature);
- name and contact details of the client;
- analytes to be determined;
- the set of samples that are to be composited for analysis, and along with compositing method (further information on compositing is provided Section 2.5.2 of this guideline);
- details of the sample matrix;
- the required sample detection limits;
- other specific instructions in the handling of the samples during the analysis (e.g. special safety precautions, analysis of both solid and liquid phase of sludge/sediment samples, notification of heavy contamination to minimise laboratory staff contact with samples and to ensure analysis equipment is appropriately calibrated.

3.4 DATA REVIEW

Following receipt of field and/or laboratory data, a detailed review of the data should be completed to determine its accuracy and validity, prior to any decisions being made based on it. The data should be checked against the DQOs specified in the SAP (refer to Section 2.2) to ensure that these objectives and the objectives of the overall program have been met. Where inconsistencies are identified, then further investigations and/or remediation may be warranted.

Laboratory data should be checked for any analytical errors, such as contamination identified in rinsate, transport and laboratory blanks, which may indicate cross-contamination of samples. Analytical data should be reviewed against field data and field observations to identify any spurious results inconsistent with field findings. Where inconsistencies are identified, re-sampling or re-analysis may be required.

4. SOIL SAMPLING DESIGN

Summary

- **Soil samples can be collected during PSIs, DSIs, remediation progress evaluations and remediation, validation and ongoing management.**
- **Sampling locations should be determined so as to provide an accurate representation of the lateral and vertical extent of contamination across a site.**
- **Where possible, control points should be identified to act as reference points in determining the levels of contamination against 'background' concentrations. Several locations for control points may be required.**

4.1 INTRODUCTION AND OBJECTIVES

Contaminated soil can arise from a number of sources, including accidental spillage of chemicals, leaching of contaminants from poorly managed landfills and leakage of chemicals from drums, tanks, pipe-work and drains.

Contaminated soils can potentially pose a threat to the environment through contributing to groundwater contamination via the leaching of contaminants through the soil profile and through uptake by plants. Contaminated sites can also potentially pose a threat to human health through the release of hazardous dusts and vapours during any reworking of the soils (such as during redevelopment of a site), through direct contact with the skin, and via ingestion.

Soil investigations generally comprise the installation of soil investigation bores using hand or power driven drilling/excavation equipment to enable the collection of soil samples representative of the soil profile. The soil samples can then be examined and analysed to determine whether adverse impacts have resulted.

Soil sampling at a site can be conducted as part of:

- PSIs to determine if further investigations are necessary;
- DSIs (sometimes staged);
- Site Management Plan, for example, remediation progress evaluations; and
- Remediation, validation and ongoing management.

For any of these, a SAP with multiple stages may be required, especially for large and/or complex sites.

Once analytical results have been received, determination of the level of contamination should be made via comparison of results against site-specific investigation and response levels, or against the DEP assessment levels as presented in the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline.

4.2 SOIL SAMPLING LOCATIONS

4.2.1 Pattern Types

The determination of soil sample locations is dependent upon the characteristics of the site and the contaminants of concern. Soil sampling locations may be based on knowledge of the site (judgemental sampling), or may be determined by a set pattern such as:

- systematic sampling (grid pattern);
- stratified sampling (sampling of sub areas);
- random sampling;
- stratified random sampling (random sampling within sub areas); and
- composite sampling (refer to section 2.5.2 of this document).

Further information on these pattern types is provided in Appendix A and *AS 4482.1-1997*.

For all sampling programs, justification for the sample locations chosen must be documented and reported to enable assessment of the results based on the location of sampling points. Where justification is not considered acceptable, particularly where limited sampling has been completed, the DEP may return the report without assessment.

As a general rule, where detailed information is available for the site in terms of physical characteristics, potential contaminants and potential sources of contamination, judgemental or stratified sampling can be applied. For example, some sites, such as former gas works, have a well-defined process layout of operations and the distribution of contaminants generally relates well to the industrial processes involved and also their particular location on the site. Where little or no information is available on potential contamination sources at a site, such as former landfill sites, then a systematic (grid) pattern of sampling may be more appropriate.

Sampling types may be combined such as a grid pattern with some judgemental sampling at locations where more information is available.

It is recommended that, where possible, control points be identified to act as a reference point in determining the levels of contamination against 'background' concentrations.

It should be emphasised that one of the goals of a SAP is to produce data which is an accurate representation of the *in situ* contamination at a site, therefore a sampling pattern should be applied so as to produce adequate information on the type, location and extent of any contamination.

4.2.2 Number of Samples

In determining the number of samples to be collected, the following should be considered:

- findings of the PSI;
- SAP objectives;
- size of the site, and final subdivided sites (if the site is to be subdivided);
- sampling pattern applied;
- depth of investigations (i.e. metre intervals, lithological changes);
- the number of stages of sampling considered feasible; and
- potential remediation and management options for the site.

4.2.2.1 Hot Spot Detection

When hot spots (areas of contamination/elevated concentration of contaminants) of a specific size need to be detected, the number of sampling points can be determined by the procedures outlined in Appendix B – Number of Sample Locations Required for Hot Spot Detection.

Appendix C – Minimum Sampling Points Required for Site Characterisation Based on Circular Hot Spots Using Systematic Sampling Pattern, should be used as a last resort, and provides the minimum number of samples required for site characterisation based on detection of circular hot spots using a systematic sampling pattern.

Appendix C should only be used where no information on the nature and extent of contamination is available or where broad-scale contamination may be present (e.g. market gardens/landfills). Sample locations should preferably be based on site-specific information in relation to geology/hydrogeology, site operations and layout, contaminant characteristics and migration pathways.

Where the minimum number of samples is collected (in accordance with Appendix C), justification is required as to why more extensive sampling was not undertaken.

The number of samples collected and the choice of sampling locations need to be justified. Where justification is not considered acceptable, the DEP may return the report without assessment.

The number of samples collected should be:

- adequate enough to indicate the lateral and vertical extent of contamination; and
- capable of detecting a 'reasonable' size hot spot in comparison to the size of the site. 'Reasonable' size should be taken to mean the largest area of contamination that could be dealt with if it were not identified during the investigation, but discovered only after development work on the site had started.

Hot spots can sometimes be identified using field monitoring techniques other than direct soil sampling. Soil-vapour analysis (e.g. active: PID for volatile hydrocarbons, and passive: sorbents for contaminants of low volatility) and geophysical techniques (for locating drums containing chemicals, unexploded ordnance, etc.) are two such techniques. Where instruments are used to detect hot spots, all equipment should be calibrated to ensure accuracy of readings. In addition, soil samples will be required to verify the results of the screening instruments.

It is not acceptable that sampling programs contain the minimum number of sampling points to be able to 'comply' with this guideline. Sampling locations should always be chosen based upon knowledge of the site, contaminants and migration pathways. Choice of sampling points should be based upon site knowledge, professional judgement and where applicable, statistical analysis.

Detailed justification of the number and locations of sampling points should be provided in relation to the site layout, areas of potential contamination, contaminant migration characteristics, site geology/hydrogeology, etc.

The sample numbers presented in Appendix C should only be used as a last resort, where little or no information is available upon which to determine sampling locations, or where it is anticipated that broad scale contamination has occurred, such as market gardens, landfills etc.

4.2.3 Sampling Depth

In order to determine the vertical extent of contamination, soil samples should be collected from more than one depth at each sampling location.

Where contamination is identified, the maximum depth (where practicable) to which that contamination extends should be determined.

Where soil contamination extends to the water table, samples of both the soil within the saturated zone and groundwater should be collected (refer to Section 6 for design of groundwater sampling programs) in order to delineate the concentration of contaminants present in both the soil and groundwater. Where soil samples are collected from the saturated zone they should be clearly identified as such in any reports and documentation.

The determination of soil sampling depths should take into consideration:

- findings of the PSI;
- SAP objectives;
- known or potential sources of contamination (e.g. surface spillage or UST(s) and pipelines);
- depth to groundwater;
- nature of aquifers beneath site;
- underlying natural soil/geology (well defined layers or infrastructure trenches/corridors present that would influence contaminant migration);
- presence of fill horizons on-site;
- type and nature of contaminants (mobility, persistence);
- length of time contaminants have been, or may have been, present at a site (which will have a bearing on the lateral and vertical dispersion of contaminants, such as smearing of profiles within a saturated zone, formation of a groundwater contaminant plume, etc.);
- field observations and identification of contaminated soil (staining, odours); and
- human health and ecological risks.

Where groundwater is encountered, drilling should continue to a sufficient depth below the static water level, or to a depth where no impact is suspected based on observation and field headspace screening (where applicable).

It may be necessary to increase the depth interval if the volume of soil recovered is insufficient to undertake the required analysis (often the case where duplicate samples are required). This will be directly dependent on the sampling method utilised.

4.2.4 Field Rankings and Headspace Analysis

Boreholes should be geologically logged by a competent professional (reference can be made to *AS/NZS 4452.1:1997 The Storage and Handling of Toxic Substances* (*AS/NZS 4452:1997*) and *AS 1726-1993 Geotechnical Site Investigations* (*AS 1726*-1993) for the unified classification system for soils), and field classified based on visual and olfactory examination. The soil description should include soil type, consistency, colour, structure, grain size, shape, sorting, particle type and cementation (carbonate soils only), moisture and origin.

Any obvious odours should be recorded, however direct smelling of any samples should be avoided.

Where the contaminants of concern are volatile organic compounds (VOCs), headspace screening may be a useful field-screening tool. Headspace screening should be undertaken using a PID, flame ionisation detector (FID) or other appropriate instrument. Information on the capabilities and limitations of these instruments is presented in *AS 4482.2-1999*. Where possible, all instruments should be calibrated on-site. Calibration documentation should be incorporated into any reports produced.

The ambient air and soil at background locations adjacent to the site should also be screened. All background concentration results should be fully documented and incorporated into any reports produced.

A number of factors affect the relationship between the overall concentration of a given contaminant in the soil and its concentration in the vapour phase. These include soil porosity, soil water content, organic carbon content, soil temperature and weathering of the contaminant. Hence the composition of volatile substances in the vapour phase may not accurately reflect their occurrence in soils. In addition, instruments used to obtain headspace results are not designed or capable of detecting individual volatile contaminants that may be present at a site. Sample analysis results are therefore required to confirm any field observations and field tests.

4.2.5 Sampling from Stockpiles and Clean Fill

Sampling from stockpiled material to be taken to landfill should be conducted according to the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001), which provide guidance on the number of samples to be collected depending on the volume of material.

Clean fill that is to be imported onto the site should be also sampled in accordance with the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001). The fill should be assessed against Ecological Investigation Levels (EILs) as per the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) unless it can be demonstrated that the material is from a clean source (e.g. borrow pit, quarry) via a letter/certificate from the source.

4.3 SAMPLING OF SOILS IN VICINITY OF USTS

When investigating a site containing USTs, the soil investigation program should initially concentrate on:

- locations selected on the basis of the infrastructure on the site, such as USTs and associated infrastructure, bowsers and oil/water interceptor traps; and
- areas of known spillage and/or leakage.

If the details of infrastructure on the site are not available it may be necessary to establish a grid of soil investigation locations over the site.

4.3.1 Factors to be Considered for Soil Sampling for the Investigation of USTs

4.3.1.1 Sample Location

Where a UST remains on-site, the following should be considered:

- samples should be collected from as close to the UST as is feasible;
- where secondary containment is present, samples should be collected from the fill material within the secondary containment to provide an indication of any leakage from the UST;
- where contamination is identified within the secondary containment, further sampling outside the secondary containment is required to confirm whether there has been leakage of contaminants from the secondary containment to the natural soils;
- where the UST is surrounded by fill material, the fill may comprise soils which are more susceptible to through-flow than the natural soils, therefore the contamination concentrations within the fill material may be lower than in the surrounding natural soils. It is therefore important to sample both the fill material and the natural soils;
- the proximity of the soil sampling location may be affected by the presence of pipe-work or by a concrete anchor over the top of the UST, especially in areas of shallow groundwater.

Where a UST has been removed, samples should be collected from immediately beneath and immediately surrounding the area where the UST was located.

It should be noted that it is not sufficient to determine the extent of adversely affected soils on the basis of site observations and field measurements. Laboratory analysis of soil samples is required for verification.

All site bore logs and field observations should be provided to the DEP as part of any investigation report.

4.3.2 Soil Sampling for the Investigation of UST Associated Infrastructure

Soil samples to determine whether the infrastructure associated with the UST(s), such as bowsers and pipe-work, have had adverse impacts may initially be limited to sampling from immediately below the potential contaminant source.

If fill material is located beneath the infrastructure it is recommended that the fill material is removed and that a sample is collected from the natural soil profile. Where contamination extends below, then additional investigations are required to determine the maximum depth of contamination.

Typical UST infrastructure and groundwater monitoring bore locations are provided in Appendix D.

4.3.3 Sample Depth for Sites Incorporating USTs

The following should be considered when determining the depth of sampling in the vicinity of USTs:

- samples should be collected from a depth greater than the base of the UST(s) and associated infrastructure to ensure that the condition of the soil below the UST(s) and infrastructure is established.
- if contamination is detected during drilling, the soil investigation bore should be continued to a sufficient depth below the base of the contamination or until groundwater is intersected.
- the sampling depth will vary on the basis of:
  - information on the UST construction and installation obtained during the PSI;
  - vertical distribution of contaminated soils encountered during drilling;
  - depth to groundwater;
  - nature of aquifers beneath the site;
  - underlying natural soil/geology (e.g. well defined layers or infrastructure trenches/corridors that would influence contaminant migration);
  - presence of fill horizons on-site;
  - nature of contaminants (i.e. if dealing with volatile contaminants such as light fraction petroleum hydrocarbons or chlorinated solvents, the vapour transport from depth through a shallow soil zone may pose a health risk);
  - field observations and identification of contaminated soil (e.g. staining and odours); and
  - human health and ecological risks.
- it is recommended that soil sampling be extended to a sufficient depth below the static water level or to a depth where no impact is suspected based on observations and field headspace screening (where appropriate), whichever is deeper, when there are:
  - indications of significant seasonal fluctuations in the depth of the groundwater table;
  - the UST has contained dense non-aqueous phase liquids (DNAPLs) (e.g. solvents);
  - where there is a history of dewatering; and
  - USTs that may have been present at the site and have been removed, but may not have been investigated.
- where soils samples are collected from below the watertable, groundwater samples should also be collected at that location in order to delineate the extent of contamination in the soil and the groundwater, and these samples should be clearly identified as such in any field documentation and reports.

It should be noted that even where no contaminated soils are detected surrounding the UST(s), the possibility for a leak from the UST(s) or the associated infrastructure remains. The presence of preferential pathways beneath a tank or the associated infrastructure means that significant impacts to underlying soil and groundwater aquifers may have occurred even though no adversely affected materials were detected by the soil investigation program. Soil and/or soil gas sampling should therefore be undertaken at other locations around the site such as site boundaries, drainage channels, infrastructure trenches, etc.

TABLE 3. SUMMARY OF MINIMUM SOIL SAMPLING REQUIREMENTS FOR SITES CONTAINING, OR PREVIOUSLY CONTAINING UST(s)

LOCATION	MINIMUM NO. OF SAMPLES FOR LABORATORY ANALYSIS	ACTION
UST (*in situ*) (natural and fill material where relevant)	Two per tank (from separate locations).	Samples should be collected from as close to the tank as is feasible and should extend to a depth below the base of the tank. Where secondary containment is present, samples should be collected from inside the containment. Where contamination is identified within the secondary containment, then samples from the material outside the containment are also required. Where fill material is present around the UST/infrastructure, samples should be collected from both the fill material and the surrounding natural soils.
UST Pit	Five per pit plus three for each additional UST in the same pit.	One sample required from the base and one from each wall of the tank pit (following the removal of backfill material). Samples should extend into natural soils.
Bowsers	One (where natural soils) Two (where fill material and natural soils).	One sample required from any fill material beneath the fuel lines and one sample representative of the surrounding natural soils.
Fuel Lines	One (where natural soils) Two (where fill material and natural soils).	One sample required from any fill material beneath the fuel lines and one sample representative of the surrounding natural soils.
Imported fill	As per stockpile sampling requirements presented in the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001).	Where fill is imported onto a site it should be 'clean fill' comprising undisturbed, natural materials. Where fill other than clean fill is used, samples of the fill material should be sampled to ensure that the fill material would not result in recontamination of the site and meet EILs.
Stockpiled Material (for disposal to landfill)	As per stockpile sampling requirements presented in the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001).	Samples should be as representative as possible and should not be collected from the surface of the stockpile (composite samples should not be collected when investigating volatiles or semi-volatiles).

5. SEDIMENT SAMPLING DESIGN

Summary

- **When undertaking sediment sampling, control points should be identified to act as a reference point in determining the levels of contamination against 'background'.**
- **Where contaminated sediments are located along a stream or riverbed, the depth and downstream extent of contamination should be identified.**
- **Where contaminated sediments are located in a marine environment, the number of samples and location of sampling is dependent upon the geographic nature of the site and the proximity of the site to pollution sources.**
- **Following remediation of contaminated sediments, ongoing monitoring may be required to ensure that re-contamination of the sediments is not occurring.**

5.1 INTRODUCTION AND OBJECTIVES

Contaminated sediments are soils, sand, organic matter, or minerals that accumulate on the bottom of a water body and contain toxic or hazardous materials that may adversely affect human health or the environment. Sediments may represent either a source or a sink of dissolved contaminants, influence surface water quality, and/or represent a source of bio-available contaminants to benthic biota (and hence potentially to the aquatic food chain). Contaminated sediments can therefore degrade ecological integrity, and pose a threat to human health when pollutants bio-accumulate in edible aquatic organisms.

Sampling of sediments as part of contaminated site assessment/remediation is required where:

- wetlands/rivers/streams form part of, or are located in the vicinity of, a contaminated site;
- a contaminated site is an aquatic environment such as a harbour, estuary, river bed, etc.;
- sediment is required to be dredged as part of port/harbour construction/expansion works or development in a riverine or marine environment.

The assessment of sediments at a contaminated site should:

- identify where contaminant concentrations are likely to result in adverse impacts on sediment ecological health;
- enable a decision to be made about the potential remobilisation of contaminants into the water column and/or into aquatic food chains; and
- identify and enable protection of uncontaminated sediments.

In addition to the sampling of sediments, pore waters within the sediments are also a source of contamination and should therefore be considered when assessing the contamination status of sediments.

Further detailed information on the assessment of sediment quality is provided in the *Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000). Where sediments are being assessed for dredging and ocean disposal, then reference should be made to the *Interim Ocean Disposal Guidelines* (ANZECC 1998). It is recommended that these documents be referred to where sampling of sediments at a site is required, and that expert advice be sought from competent professionals to ensure that the correct methodologies are employed.

Once analytical results have been received, identification of the severity of contamination should be made via comparison of site-specific investigation and response levels, or against the DEP adopted assessment levels as presented in the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline.

5.2 SEDIMENT SAMPLING LOCATIONS

5.2.1 Pattern Types

When determining a sampling pattern the following should be taken into consideration:

- findings of the PSI;
- objectives of the SAP;
- current and historical usage of the site;
- known and potential contaminants (and their distribution);
- nature of contaminants;
- beneficial uses of the site and adjacent sites;
- potential/proposed site use(s);
- climatological conditions;
  - tidal influence (may inhibit ongoing access to the sampling location); and
  - seasonal variability of temperature, wind direction and wind force (e.g. wave movements may restrict sampling location access, storm conditions may disturb sediments to be sampled);
- hydrographical conditions;
  - mobility of sediments (dynamic zones can result in sediment mobilisation enhancing contaminant release, and sediment deposition and sorting of grain sizes);
  - tidal areas (e.g. variations in water depth, current speeds and directions);
  - rivers (e.g. flow rates, geophysical condition of bed areas i.e. riffles versus pools);
  - standing bodies (e.g. lakes and harbour areas may have negligible current to cause sediment disturbance);
  - sediment conditions (e.g. nature and composition of sediment layer, sorting of sediments, sediment depth);
  - influence of stream mixing; and
  - mixing through the profile from wave action;
- nautical conditions (the influence of marine traffic (e.g. some sample points may need to be avoided due to traffic));
- sampling constraints;
  - physical constraints (e.g. boat size, water depth); and
  - safety of sample collection (e.g. presence of soft mud, quicksand, deep holes, swift currents and dangerous marine life);
- contaminant characteristics;
  - solubility, density, persistence and type of contaminants; and
  - proximity of sampling location to outfalls and sources of contamination;
- ecological considerations;
  - plant growth (e.g. disturbance of plant growth and restrictions on access to plant growth (algae on surface of water body, and riverbank vegetation)); and

  - possible impacts on aquatic organisms (e.g. dispersion of contaminated sediments, disturbance of breeding grounds (timing of site access)); and
- potential risks to human health and the environment.

As with soils, where detailed information is available for the site in terms of physical characteristics, potential contaminants and potential sources of contamination, then judgemental sampling can be used to investigate contamination. Where there is little or no data in relation to the potential contamination of the site, then a systematic (grid) sampling pattern should be adopted. Sampling types may be combined such as a systematic (grid) pattern, with judgemental sampling at locations where more information is available. Refer to Appendix A for further information on various sampling patterns.

It is emphasised that a goal of a SAP is to produce data which <u>is an accurate representation of the *in situ* contamination at a site</u>; therefore a sampling pattern should be applied so as to produce adequate information on the type, location and extent of any contamination.

Where large sites are being assessed, such as bays, harbours and marinas, where little information on contamination is available, it is recommended that:
- the site be divided into sub-areas and then random samples collected from within each block. Sub-area size can be varied to increase sampling density in locations with greatest probability of high contamination levels, and areas can be large if evidence indicates contaminant concentrations are unlikely to vary much across the site; or
- a pilot study should be completed comprising 10-20% of the locations anticipated for the full-scale study. Pilot samples should be analysed for the full range of chemical parameters anticipated to be present.

5.2.2 Sampling Depth

Determination of the depth of sampling should take into consideration:
- findings of the PSI;
- objectives of the SAP;
- site history and possible depth of contamination through deposition;
- sediment geology (natural confining layers, preferential pathways);
- nature of contaminants (mobility, persistence);
- known or assumed maximum depth of contamination;
- field observations and identification of contamination (e.g. stained sediments);
- diffuse or point source contamination sources (diffuse contamination within a harbour, or point source contamination at depth from a pipe discharge);
- potential for mixing down the sediment profile; and
- human health and ecological risks.

5.2.3 Number of Samples

Determination of the number of samples to be collected should take into consideration:

- findings of the PSI;
- SAP objectives;
- size of the area to be sampled;
- sampling pattern applied;
- nature, complexity and distribution of known contaminants;
- sediment lithology and variability;
- potential remediation and management options; and
- small-scale variability in contaminant concentration.

Control points should be set up/identified to act as a reference point in determining the levels of contamination against ‘background’.

5.2.3.1 Inland Sediments

As with soil sampling programs, the number of samples is dependent upon the site history, distribution of contaminant sources and migration pathways of contamination. Where contaminated sediments are located along a stream or riverbed, the depth and downstream extent of contamination should be identified. Where water flow may have carried contamination downstream, samples should be collected progressively downstream, at regular intervals, from the contamination source and in areas where sediments are likely to settle (e.g. deep pools) until the extent of contamination is determined.

5.2.3.2 Marine Sediments

Where sampling of marine sediments is being undertaken such as in a harbour, marina, port or estuary, the number of samples will be dependent upon the geography of the sampling location:

- where sediments are located at a site which is relatively uniform (e.g. in the centre of a large, flat-bottomed or gently sloping bay) and the site is distant from pollution sources (e.g. the centre of a large bay), then a minimum number of samples can be collected to adequately characterise the contamination status; whereas
- where sediments are near the shore in a geographically complex embayment, with significant changes in depth, shoreline configuration and many potential pollution point sources (e.g. Cockburn Sound), then a larger number of samples will be required.

Justification as to the number of samples required must be documented and incorporated into any reports. Where justification is not considered acceptable, the DEP may return the report without assessment.

5.2.4 Frequency of Sampling

There is often some form of mobility of sediments, and therefore more than one sampling event may be required to build up a picture of temporal changes in sediment quality. Determination of sampling frequency should take into consideration:

- objectives of the SAP;
- seasonal and diurnal changes in sediments due to tidal influences, etc.;
- sediment geology and stratification; and
- characteristics of particular contaminants (e.g. mobility, partitioning, etc.).

Following remediation of contaminated sediments, ongoing monitoring may be required to ensure that re-contamination of the sediments in the area is not occurring (e.g. through contaminated water flowing over the site, or discharges from unknown or remote contamination sources).

6. GROUNDWATER SAMPLING DESIGN

Summary

- **Assessment of groundwater is required during contaminated site investigations unless it can be demonstrated to the DEP that there is no potential for groundwater to be contaminated.**
- **A minimum of three groundwater monitoring bores should be installed on a site to enable triangulation of water levels and provide an indication of groundwater flow direction beneath the site.**
- **A SAP should include the location, depth, construction, sampling details (methodologies and frequency) and analytical methods for groundwater monitoring at a site.**
- **The construction of groundwater monitoring bores should take into account the nature and characteristics of the contaminants of concern and the local geology.**
- **Accurate monitoring bore installation is required to ensure that contamination is not dispersed through breaching of aquitards into adjacent aquifers.**
- **The use of existing monitoring bores or boreholes should not be considered unless they can be shown to be suitable for the purpose of the sampling program (e.g. bore construction within correct aquifer, adequate construction, suitable sampling points, etc.).**

6.1 INTRODUCTION AND OBJECTIVES

Due to the often shallow and vulnerable nature of groundwater resources in Western Australia, the potential for groundwater impact should be determined for each site. Where groundwater is identified as being present at a site, particularly at shallow depths, it may provide a pathway for migration of contamination both within and across site boundaries.

Groundwater investigations are required at a site unless it can be demonstrated to the satisfaction of the DEP that there is no potential for groundwater at the site to be contaminated.

Groundwater investigations generally comprise the installation of monitoring bores to obtain information on the depth to groundwater beneath the site, determine groundwater flow direction and facilitate the collection of samples which reflect the spatial and temporal variation of the chemical composition of groundwater at the site.

Generally a minimum of three monitoring bores should be installed on a site to enable triangulation of water levels. This provides information on groundwater flow direction beneath the site. Normally, however, it is advisable to define the watertable surface in more detail, as this can be locally complex. It is recommended that specialist hydrogeological advice be sought in the selection of the most appropriate sampling locations. Table 4 provides a summary of the minimum requirements for groundwater sampling.

Grab samples of groundwater collected from the base of test pits or excavations are not acceptable due to the possibility of alteration of the sample by ambient conditions (e.g. temperature, oxygenation, ultraviolet light and presence of dust and particles).

Prior to installing groundwater monitoring bores at a site, any existing bores on, or in the immediate vicinity of, the site should be identified to assist in determining the beneficial use of groundwater in the vicinity of the site (e.g. public supply abstraction wells, domestic irrigation or other monitoring bores). The beneficial use of groundwater and/or bore locations may need to be determined by a door-knock survey of surrounding properties/residences.

The use of existing bores for sampling points should not be considered unless they can be shown to be suitable for the purpose of the sampling program (i.e. that they are constructed so as to intercept the contaminants of concern).

Where UST(s) and associated infrastructure have been installed according to the Australian Institute of Petroleum (AIP) Codes of Practice CP-4-1001 *The Design, Installation and Operation of Underground Petroleum Storage Systems* and Australian Standards, monitoring bores may already have been installed at the site and can be used as an initial indication of contamination.

Enquiries regarding groundwater can be made to the WRC. The WRC maintains a database of groundwater bores throughout the state. However, this information is often limited in coverage and the integrity of the data cannot be guaranteed. The *Perth Groundwater Atlas* (WRC, 1997)[1] provides some indication of the depth and flow direction of the local groundwater aquifer in the Perth area. It is recommended that this publication be used as a guide only, as the information is heavily based on regional groundwater bore data, and is not appropriate, or intended to be used, for site-specific contamination investigations. When determining whether groundwater sampling and analysis is required, the following should be taken into consideration:

- findings of the PSI;
- objectives of the SAP;
- on-site and off-site sources of contamination;
- permeability of the strata on the site;
- known or expected depth to the local groundwater;
- groundwater flow direction and discharge location;
- ambient groundwater chemistry;
- where soil contamination indicates the potential for groundwater contamination;
- quantity of contaminant and its mobility characteristics (persistence, solubility, density, stability, partitioning characteristics);
- soil structures which indicate possible conduits;
- potential receptors (abstraction bores e.g. drinking water supply, domestic irrigation and the aquatic environment - freshwater or marine); and
- whether the site is located within a wetland Environmental Management Area, Underground Water Pollution Control Area (UWPCA), or Public Drinking Water Source Area (PDWSA).

Once analytical results have been received, identification of the severity of contamination should be made via comparison to site-specific investigation and response levels, or against the DEP adopted assessment levels as presented in the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline.

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[1] The updated version of the *Perth Groundwater Atlas* (WRC, 1997) and the *Hydrogeological Atlas of Western Australia* is available on the Water and Rivers Commission (WRC) website, www.wrc.wa.gov.au.

6.2 GROUNDWATER SAMPLING PROGRAM

6.2.1 Factors to be Considered

The objectives of a groundwater SAP should generally be to determine:

- the source of contamination (may have been determined by soil sampling program);
- piezometric (water table) contours and local direction(s) of groundwater flow;
- nature and severity of groundwater contamination;
- vertical and lateral extent of contamination;
- potential impacts of groundwater contamination on each of the existing, likely future, and possible uses of groundwater; and
- the discharge location for groundwater.

Determination of groundwater sampling locations should take into consideration:

- findings of the PSI;
- objectives of the SAP;
- depth to groundwater (and seasonal variations in depth);
- characteristics of the aquifer/saturated zone that is being sampled (unconfined or confined aquifer type, vertical and horizontal in-homogeneities, etc.);
- hydraulic gradient;
- direction of groundwater flow (and seasonal variations in flow direction - net flow versus seasonal flow);
- presence of any groundwater bores at, or in the vicinity, of the site (monitoring bores, extraction bores);
- expected contaminant migration pathways;
- potential risks to uncontaminated aquifers and/or surface water resources; and
- risk to human health or the environment (through disturbance of contamination, extraction of contaminated water).

6.3 INSTALLATION OF GROUNDWATER MONITORING BORES

Drilling, construction and development of bores can affect groundwater sample quality through the introduction of physical or chemical effects or unwanted residues.

The key factors that need to be considered for the installation of groundwater monitoring bores are listed below. For further information reference can be made to Water Quality Protection Note *Monitoring Bores (Slotted Casing)* (WRC, 1999).

6.3.1 Selection of Bore Locations

The location of the monitoring bores should be selected so as to:

- be beneath or immediately down-gradient of the most likely source of contamination (UST, fuel lines, bowsers, spill locations, drum storage areas, etc.);
- provide information on the background water quality at the site (up-hydraulic gradient boundary); and

- provide information on the quality of the groundwater leaving the site (down-hydraulic gradient boundary).

Table 4 provides a summary of minimum groundwater sampling requirements.

TABLE 4. SUMMARY OF MINIMUM GROUNDWATER SAMPLING REQUIREMENTS

LOCATION	MINIMUM NUMBER OF BORES	ACTION
Beneath or immediately down-gradient of any contamination sources.	One per contaminant source. Further bores may be required to determine the lateral extent of contamination if identified.	Soil samples should be collected, logged and analysed during the installation of the groundwater monitoring bores. The construction of the bores, particularly the location of the screened interval, is dependent on the hydrogeological properties of the site and the contaminants of concern (DNAPLs/LNAPLs, etc.).
Site Boundary – hydraulically down-gradient.	One per site* Further bores may need to be installed off-site to determine the extent of any contamination migrating off-site.	
Site Boundary – hydraulically up-gradient.	One per site*.	

* A minimum of three groundwater monitoring bores per site is required to enable the local groundwater flow direction to be determined.

6.3.1.1 Investigation of Diffuse Groundwater Contamination

Sampling of diffuse source groundwater contamination should take into account the groundwater flow-field and landuse distribution variability. The impact of regional diffuse sources tends to increase the average concentrations of contaminants within an impacted flow field in comparison to contaminant concentrations up-hydraulic gradient. When investigating diffuse groundwater contamination, the following should be considered:

- in the case of known groundwater contamination, purpose-drilled bores should be completed and screened over different depth intervals of the aquifer depending on the likely migration pathways of the contaminants (e.g. contaminant density and estimated hydrogeological parameters);
- the use of existing sampling points (e.g. abstraction/pumping bores) can provide integrated samples from a large volume of the aquifer. However, where there is low-intensity pollution, this may not be appropriate due to potentially diluting contamination levels, and in these circumstances smaller-capacity bores should be used;
- sampling bores should be located throughout the area of interest. The sites should be chosen to represent the different hydrogeological and landuse conditions, and areas considered to be particularly vulnerable to diffuse pollution; and
- sampling bores should be located up-hydraulic gradient and down-hydraulic gradient of any identified contamination to obtain information on the extent of contamination. A minimum of three bores should be constructed at a site to determine groundwater flow direction.

6.3.1.2 Investigation of Point-Source Groundwater Contamination

When specifying sampling points to monitor point-source pollution (e.g. from a large chemical spill location or leaking tank), it is necessary to consider the location of the point source in relation to both the regional and seasonal groundwater flow direction(s). Where practical, sampling bores should be installed at the following locations:

- directly beneath the pollution source;
- progressively at distances down-hydraulic gradient from the contaminant source, and perpendicular to the groundwater flow direction, at a range of depth intervals based on contaminant density and estimated hydrogeological parameters; and
- up-hydraulic gradient from the source of contamination, so the areal extent of the pollution plume can be identified. These bores may also provide information on the background groundwater quality.

Where groundwater contamination is identified, the extent of contamination should be determined in order to identify:

- if the contamination is migrating off-site and impacting adjacent properties (i.e. bores at site boundary, bores at down-gradient off-site locations);
- if contamination is migrating on-site from up-gradient sources (i.e. bores at up-gradient site boundary); and
- whether contaminants are at concentrations high enough to warrant active remediation.

6.3.2 Drilling

A drilling technique should be chosen which is the least disruptive to the zone to be monitored as it is preferable that the physical conditions of the aquifer are maintained as close to pre-drilling as possible.

Drilling techniques can cause smearing (e.g. rotary auger) and compaction (e.g. cable tool) of borehole walls and may cause transport of geological formation materials and drilling fluids into different zones. This can result in groundwater and contaminant pathway blockage, thereby excluding contamination from the monitored material.

It is essential that hydrogeological conditions be researched prior to drilling to minimise the risk of penetrating aquitards that can result in further vertical dispersion of contaminants.

Where monitoring bores are required to be drilled through a contaminated upper zone into a potentially uncontaminated lower zone, isolation casing must be installed in the contaminated zone, and the aquitards sealed (reinstated) to prevent migration of contamination between zones during drilling. A qualified and experienced driller must complete these works under the direction of a competent professional, using correct construction materials.

A competent professional should log the bores (reference can be made to *AS/NZS 4452.1997* and *AS 1726-1993* for the unified classification system for soils). Geological data collected during drilling and sampling activities should enable the determination of the specific method of groundwater sample collection and completion intervals for the installation of monitoring bores.

6.3.2.1 Drilling Fluids

Drilling fluids are used during the drilling process to remove cuttings from the borehole, to clean and cool the bit, to reduce friction between the drill string and the sides of the borehole, and to hold the borehole open during the drilling operation.

Drilling fluids used include air, water and specific drilling mud formulations or native clay slurries. They can have a range of effects on groundwater quality:

- air may cause oxidation and precipitation of analytes of interest, such as dissolved metals or, if contaminated with lubricants necessary for compressor operation, may introduce hydrocarbons into groundwater;
- air may also cause severe disturbance of hydrochemical profiles in highly permeable formations;
- water may dilute or flush groundwater near the bore, changing the chemistry of the groundwater;
- water may also cause precipitation of minerals, thereby blocking contaminant and groundwater pathways (i.e. pores and fractures);
- mud may enter the formation and seal preferential groundwater pathways, or clay particles within mud may absorb some electrically charged contaminants (e.g. dissolved metals); and
- the use of additives in mud (e.g. surfactants and drilling detergents) to overcome drilling difficulties increases the potential for introduction of physical and chemical changes.

Since these effects are frequently permanent, it is important to record the drilling method, the fluids used and details of bore development before sampling.

6.3.3 Bore Construction

6.3.3.1 Casing and Screening

The construction of groundwater bores is dependent upon the contaminants of concern.

Casing and screen materials should be chemically compatible with the contaminants of concern and the immediate groundwater environment. If incompatible, either leaching or sorption of analytes may result, while desorption of analytes may occur should water quality change. Diffusion of organics may also occur through polymeric casing materials.

In extreme cases, acidic environments may cause corrosion of metal casing while solvents may dissolve PVC casings. This may cause immediate effects on water quality in the bore and the potential for water from different depths to migrate along the borehole.

Casing and screen materials should be washed on-site with an organic based detergent or obtained washed and sealed. If casing joints are inappropriately constructed, they may cause leakage. Solvent-bonded casing joints, which are prone to solvation, should not be used when sampling for organics. Hydrocarbon-based glues should be avoided for the joining of casing as they are likely to affect sampling results. Threaded casing is preferable.

6.3.3.2 Annular Fill and Gravel Pack

The annular space is the space between the borehole walls and casing or screen. The materials used in the annular space include filter pack materials, such as gravels and fine sand and seal materials, such as bentonite, bentonite/cement mixtures and cement. Any of these materials, when inappropriately used or installed, may alter the chemistry of groundwater entering the bore and need to be considered during bore installation. Cement, for example, may cause a change in pH, while bentonite may sorb dissolved metals.

6.3.3.3 Location of Sampling Point (Screen Depth and Length)

The location and length of the screened interval in groundwater monitoring bores can be vital. Due to the generally laminar flow of groundwater, contaminated groundwater usually flows in discrete zones. Poorly placed screens may fail to intercept these zones. Long screens in monitoring bores are known to result in dilution of groundwater samples due to mixing with uncontaminated groundwater, resulting in the collection of unrepresentative samples. Ideally, screened intervals should be short and located specifically within the zone of interest. In some investigations, bores may need to be installed at more than one depth in an aquifer to assess the extent of vertical groundwater flow and the distribution of contaminants at depth.

Correct location of the screened interval is especially critical when dealing with aquifers polluted with non-aqueous phase liquids (NAPLs).

6.3.3.4 Light Non-Aqueous Phase Liquids (LNAPLs)

LNAPLs have an average density less than water (specific gravity of less than one) and therefore generally float on water (e.g. petrol, diesel and other petroleum products).

Where LNAPLs are present or potentially present, monitoring bores should be constructed with vertical, overlapping, slotted intervals with a continuous screen or with a spiral screen to ensure accurate measurement of phase separated product.

Bores should be constructed to ensure that the watertable on the site is at a depth within the slotted interval of the groundwater monitoring bore (often one metre of screen above the watertable and at least two metres below).

If multiple aquifers exist at the site nested or multi-port monitoring bores may need to be installed to facilitate sampling over several aquifer intervals.

It is desirable that the screen for the detection of LNAPLs is constructed as close to vertically continuous as is possible.

Where a bore has been installed to monitor for LNAPLs, prior to purging, the bore should be monitored for the presence of separate phase product using appropriate equipment, such as an oil/water interface probe.

6.3.3.5 Dense Non-Aqueous Phase Liquids (DNAPLs)

DNAPLs have an average density greater than water (specific gravity greater than one) and will generally sink in groundwater. It should be noted that a mixture of compounds might contain DNAPL compounds but behave as an LNAPL if the average density is less than that of water (e.g. a trace of TCE in oil).

The construction of groundwater monitoring bores will be dependent upon the total depth of the aquifer beneath the site and the presence and locations of any impermeable horizons.

Groundwater monitoring bores for the detection of DNAPLs should be constructed such that the screened interval extends over the full depth of the aquifer or is located immediately above any impermeable horizons that are identified. Depending upon the site characteristics it may be beneficial to construct a nest of groundwater monitoring bores with screened intervals at varying depths throughout the aquifer to enable a vertical profile of the DNAPL contaminant concentrations to be developed.

6.3.4 Bore Development

This is the process of removing fines such as sand, silt and clay from the aquifer around the bore screen and breaking down drilling mud on the borehole wall. Development maximises the hydraulic connection between the bore and the formation.

In most formations, the application of development techniques will result in 'virtually particulate-free' water returns from bores. However, development techniques are limited for small-diameter monitoring bores (i.e. 50 millimetres in diameter or less) and in low yielding geological formations. In such conditions, bore development may not result in samples with low turbidity.

During development, bore yield should be estimated by monitoring the rate of recovery of water in the bore after pumping. This information can then be used to select suitable methods for subsequent purging and sampling.

All bores used for groundwater monitoring should be developed prior to sampling where grouting has been used in the construction processes, bores should be developed after the grout has had sufficient time to cure and it can be demonstrated that bore field chemistry has stabilised.

6.3.5 Bore Completion

Groundwater monitoring bores should be labelled as such and have a lockable cap to avoid tampering and contamination.

The elevation of the top of well casing and ground level should be surveyed to the Australian Height Datum (AHD) or to a local height datum. All monitoring bores should be accurately surveyed (suggest a one millimetre elevation accuracy between-bore elevation) to allow for presentation of accurate watertable contours. Combining the bore elevation with the depth to groundwater data enables a groundwater contour diagram for the site to be developed and the direction of the local groundwater flow to be determined.

6.3.6 Documentation

Documentation and reporting of bore construction details is vital, and should include date drilled, drilling method used (e.g. mud rotary, direct push, etc.), time started, time completed, drilling company, name of drilling supervisor, construction depth, tagged depth, screen interval, depth to water, details of bore development (method of development, time to develop, yield, etc.). A typical bore construction log is presented in Appendix E.

Although at this stage there is no requirement for the licensing or registering of groundwater monitoring bores with the WRC, the provision of bore logs and groundwater information to the WRC improves the database and consequently the information obtainable from this source.

6.4 GROUNDWATER SAMPLING

Groundwater samples should only be collected from appropriately constructed groundwater monitoring bores. Samples of groundwater collected from test pits, trenches or similar are not acceptable, as they are not considered representative of groundwater at a site.

Sampling of monitoring bores is not discussed in detail in this document, however the following factors should be noted:

- accurate water level measurements are required from all bores to provide an indication of groundwater flow direction beneath the site and any temporal variations in groundwater level or flow direction.
- where a bore has been installed to monitor for LNAPLs, prior to purging, the bore should be monitored for the presence of phase separated product using appropriate equipment, such as an oil/water interface probe.
- if phase separated product is detected in the groundwater monitoring bore, consideration should be given to correcting the groundwater elevation to allow for the difference in density of the product and groundwater.
- all instruments used on a site should be accurately calibrated. Water level probes can stretch over time and should be regularly calibrated. Where a number of instruments are being used on a site (e.g. different water level probes or an oil/water interface probe), then calibration between instruments is required to ensure accuracy and consistency of results.

6.4.1 Groundwater Level Measurement

Groundwater level measurements are required to determine groundwater and contaminant flow directions and rates.

Some important factors to consider when collection of measurement data should include:

- groundwater levels should always be measured and recorded on the same day (date and time) to the Australian height datum before bore disturbance;
- groundwater levels in new bores may take some time to stabilise after installation and development;
- in some environments, irrigation, pumping or tidal influences may cause rapid groundwater level fluctuations;
- in some situations water can accumulate in bores so consideration of groundwater level measurements before and after purging of the bore may be necessary; and
- methods and instruments used to collect and record changes in the level of groundwater can vary depending on the design and need to be considered.

6.4.2 Purging

Purging is the process of removing stagnant water from a bore before sampling, therefore may not be representative of the aquifer conditions. Boreholes should therefore be purged before sampling, by pumping to waste a volume of water equivalent to at least four to six times the internal volume of the borehole itself.

Purging also involves pumping the water out of the bore until *in situ* measurements such as pH, turbidity, electrical conductivity (EC), temperature, etc. are in equilibrium. The purging process for monitoring bores should not introduce air, water or other materials into the aquifer.

Further information can be obtained from *AS/NZS 5667.11:1998 Water Quality – Sampling, Part 11: Guidance on Sampling of Groundwaters* (*AS/NZS 5667.11:1998*).

6.4.3 Frequency of Sampling

Groundwater quality may vary temporally and spatially due to seasonal fluctuations in groundwater level and groundwater flow directions. Groundwater beneath a site may therefore need to be sampled on more than one occasion. Determination of the frequency of groundwater sampling events should take into consideration:

- objectives of the SAP;
- variation in quality of the groundwater under investigation (temporal and spatial);
- nature and type of contaminants (mobility, dispersion, specific gravity); and
- analysis results and/or continuous monitoring results, which indicate that groundwater contaminant concentration(s) exceeds acceptable concentrations or appears to be changing.

6.4.3.1 Disposal of Extracted Waters

Extracted groundwater, resulting from development and purging of bores and sampling activities should be stored on-site in lined drums on an impervious surface until the analysis results are available to determine the most appropriate disposal option. This is of particular importance where separate phase product is present in the groundwater.

Where site contamination is known, or where it is determined that there is a high probability of contamination, it is recommended that the disposal options for any material requiring removal from a site during sampling activities be addressed prior to commencing works so as to:

- minimise health and safety risks to public, site personnel and the environment associated with exposure to any contaminated material;
- determine a strategy/method for characterising the waste;
- determine the packaging requirements for waste material to be disposed so as to reduce the risk of costly and unsafe double handing; and
- minimise time taken to obtain the appropriate approvals for off-site disposal.

Where the concentration of contaminants in the wastewaters is below the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) guideline or DEP approved site-specific criteria, then they may be disposed of on-site at a suitable location following approval from the site operator/owner, any interested party or authority. Disposal should not be to any surface water bodies, stormwater drains or to sewer (unless prior approval has been obtained from the relevant authority).

Where the concentrations of contaminants are such that they are unable to be disposed of at the site, then off-site disposal at an appropriate location, such as a liquid waste disposal facility is required. Such facilities require a licence under the *Environmental Protection Act 1986*. Any waste considered a controlled waste must be appropriately transported in accordance with the *Environmental Protection (Controlled Waste) Regulations 2001*. For further advice about licence and permit requirements, please contact the DEP.

7. REMEDIATION, VALIDATION AND ONGOING MANAGEMENT

Summary

- **The objective of conducting remediation, validation and ongoing management sampling is to assess whether contaminant concentrations in the material remaining on-site pose a risk to human health or the environment and are acceptable for the intended or current landuse.**
- **Validation of soil remediation should be completed by systematic sampling across the walls and base of all excavations.**
- **Practitioners should confirm that the history of any backfill material indicates that it is not contaminated.**
- **Validation of sediment remediation should be completed by systematic sampling of the remediated area. Re-dispersion of sediments to and from the area should be considered when determining sampling locations and sample depth.**
- **Validation of the acceptability of groundwater should be completed by conducting an ongoing monitoring program until consecutive/seasonal results show either a decrease or stability in contaminant concentrations below the relevant assessment levels.**

7.1 INTRODUCTION AND OBJECTIVES

The objective of conducting remediation, validation and ongoing management sampling is to assess whether contaminant concentrations in the materials remaining on-site (i.e. soil/sediment/groundwater, backfill material, *in situ* and *ex situ* remediated material, etc.) pose a risk to human health or the environment and are acceptable for the intended or current landuse.

Where contamination above acceptable levels is identified during a validation program then the following should be completed:

- review of sampling, analytical and QA/QC results to determine if any errors in sampling/analysis have occurred;
- further investigations to determine the extent of the remaining contamination;
- further remediation to ensure that contamination is not present above acceptable levels;
- validation of the further remediation; and/or
- site based ecological and/or human health risk assessment to determine the impacts of the contamination remaining on-site (which should address all exposure pathways).

The use of PID and other similar field/visual/olfactory methods are not acceptable methods of validation.

UNDERGROUND STORAGE TANK (UST) AND INFRASTRUCTURE REMOVAL

It should be noted that where UST(s) have contained petroleum products, the removal, disposal and *in situ* abandonment of those tanks should be undertaken in accordance with the *Guidance Note S321 Removal and Disposal of Underground Petroleum Storage Tanks* (DME, 1999).

The following factors should be considered when removing tanks and infrastructure:
- **All product lines should be flushed and any residual products removed by an appropriate contractor prior to the commencement of works for the removal of the USTs.**
- **The integrity of the pipe-work (especially where connections occur) should be established by an approved person (refer to *Guidance Note S321*) prior to the removal of the UST. Upon removal, the UST should be examined for evidence of corrosion, pitting, splitting (especially at seams) and any evidence of leakage from fittings noted.**
- **Photographic evidence of the condition of the UST, upon removal, should be obtained. It is also beneficial to provide photographic evidence of the condition of the tank pit following removal of the UST.**

A disused UST may be left in the ground only in exceptional circumstances and subject to approval by the DMPR. The following will be considered when application for *in situ* abandonment of USTs is undertaken:
- **The removal of the tank would bring significant risk to the structural integrity of the nearby buildings or structures.**
- **A competent professional can demonstrate to the satisfaction of the DEP that the risks of contamination of the surrounding soil and groundwater are acceptable. The DEP may require the implementation of a monitoring program.**

7.2 VALIDATION SAMPLING PATTERN SELECTION

7.2.1 Remaining *In Situ* Soil

Where contaminated soil is removed from an area, the soil remaining in the excavation should be validated as being acceptable prior to backfilling. A systematic sampling pattern should be used with sampling points spaced evenly across the walls and the bottom of all excavated areas. The grid spacing should correspond to the number of samples required as discussed in Section 4.

Validation samples should be collected:
- from the walls of the excavation pit at depth intervals dependent upon the location of contamination; and
- from the bottom of the excavated pit.

7.2.1.1 Validation of USTs and Associated Infrastructure

Where a UST has been removed, validation of remaining *in situ* soil should take into consideration:

- imported material located in the tank pit surrounding a UST should be sampled. It is preferable that the imported fill be removed, so that the natural soil profile is exposed for validation;
- validation sampling following the removal of a single UST should consist of a minimum of one soil sample from the base of the tank pit and one sample from each wall of the tank pit. Validation samples should also be collected from beneath the locations of each bowser and beneath each fuel feed line;
- to validate a multiple tank pit the number of soil samples should be increased such that a similar sampling density is obtained to that used for the validation of a single tank pit (see Appendix F);
- in most instances it is recommended that samples are representative of the natural soil profile, whether this is the sidewall, base of the tank pit or beneath bowsers or fuel lines;
- if groundwater is evident in the base of the tank pit, the wall soil samples should be collected from within the capillary fringe of the groundwater aquifer to maximise the probability of detecting any contaminated soils (in addition, groundwater monitoring bores should be installed and groundwater samples collected and analysed – collection of grab samples from within test pits, trenches or similar is not acceptable (refer to Section 6)).

Where a UST has been removed, Appendix F provides suggested sampling locations to validate a tank pit following UST removal.

Refer to Section 4 ‘Soil Sampling Design’ for further information.

7.2.2 Remaining *In Situ* Sediment

Validation of sediment remediation should be completed by systematic sampling of the remediated area (i.e. a grid pattern including collection of samples along the perimeter of the remediated area and immediately beyond the remediated area), to check that no dispersion of contaminated sediments has occurred.

The number of samples required will be dependent upon the size of the area remediated, any dispersion of sediment which occurred during remediation activities, any movement of sediment into the remediated area, and the nature of the contaminants.

The depth of sample collection will depend upon the depth of initial contamination, the remediation depth and the presence of any sediment which has moved onto the site following remediation.

In high sediment movement areas, the remediation area may become in-filled with clean sediments, and it is therefore important to select the most appropriate methodology to ensure that sediment from the zone of contamination is collected rather than clean sediments.

Where the source of contamination is unknown, ongoing monitoring should be undertaken to ensure that re-contamination of sediments does not occur (e.g. by contaminated water flowing over the sediments, or by contaminated sediments settling in an area distant from their source).

Refer to Section 5 ‘Sediment Sampling Design’ for further information.

7.2.3 Groundwater

Accurate validation of contaminated groundwater or of the improvement in groundwater quality is difficult due to inherent variability in groundwater quality, and sampling and analysis error. One set of groundwater monitoring results is not enough to confirm validation of a site.

In order to adequately validate groundwater:

- seasonal trends must be identified, and information provided to demonstrate that the groundwater is of acceptable quality the whole year round, as concentrations of contaminants may change due to seasonal variations in groundwater level; and
- all results must show a consistent trend such as a decrease or stabilisation below the relevant assessment levels. A sudden drop in contaminant concentrations is not considered an adequate validation of reduced contamination, as it may be a result of sampling/analysis error as opposed to actual groundwater conditions. In addition there may be "rebounding" towards original contaminant levels following groundwater remediation (e.g. by residual non-aqueous phase liquid (NAPL)), sorbed or otherwise immobilised contaminants being redissolved in groundwater. Although some indication of rebound may be seen following monitoring for a full year, in some cases it may take considerably longer.

Where active remediation is being undertaken, and analytical results show contaminant concentrations are within acceptable limits, then an adequate monitoring trial should be undertaken prior to cessation of remediation activities to ensure that when active remediation ceases, contaminant concentrations do not return to above acceptable limits when the groundwater returns to equilibrium. Also a period of monitoring after active remediation ceases to confirm successful remediation.

Refer to Section 6 'Groundwater Sampling Design' for further information.

7.2.3.1 Monitored Natural Attenuation (MNA)

Natural attenuation is often presented as a remedial method for groundwater. Although it is recognised that natural attenuation is an effective, inexpensive clean-up option and in some cases the most appropriate way to remediate a site, it is not the DEP's preferred method of management or remediation of groundwater (more active measures such as sparging or dosing are preferred). As with any remedial option, natural attenuation should be evaluated for its appropriateness based on the risks, the site characteristics, and the potential to achieve remediation at a site. The capacity for the aquifer to attenuate contaminants needs to be demonstrated (e.g. dissolved oxygen measurements, pH, sulphate, nitrate, ferrous iron, contaminant-utilising bacteria, and heterotrophic bacteria).

To be accepted as a viable remedy, natural attenuation needs to be used in the context of a carefully controlled and monitored site clean-up approach, including source removal. Because the rates of natural degradation processes are typically slow, long term monitoring is necessary to demonstrate that contaminant concentrations are decreasing at a rate sufficient to ensure that they will not become a threat to human health or the environment, and that transport through the subsurface is as predicted. Continuation of groundwater monitoring is required until such time as the contaminants of concern have decreased to below the relevant acceptance level.

7.2.4 Backfill Material

Backfill material may be imported from either on-site or off-site sources.). The fill should be assessed against Ecological Investigation Levels (EILs) as per the *Assessment Levels for Soil, Sediment and Water* (DEP, 2001) unless it can be demonstrated that the material is from a clean source (e.g. borrow pit, quarry) via a letter/certificate from the source..

The number of samples required is dependent upon the volume of fill material. Sampling should be completed in accordance with the stockpile sampling guidelines provided in the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001) and the results assessed against EILs as per *Assessment Levels for Soil, Sediment and Water* (DEP 2001).

Indication of the quality of all backfill material at a site is required. Where fill is sourced from a number of locations documented evidence and/or analysis results for each fill source is required, along with a list of the volumes obtained from each source. Where fill is imported, it generally becomes the surface material of the site, therefore confirmation of its quality is required to ensure minimal risk to human health and the environment.

7.2.5 Remediated Material

Excavated material should be sampled to determine appropriate disposal or remediation options.

The material can be sampled *in situ* using a systematic (grid) sampling pattern to demonstrate that the material excavated/dredged is not likely to pose an unacceptable risk to human health or the environment. Judgemental sampling, based on previous investigation results, can be used to validate areas considered most likely to have remained contaminated.

Where material is stockpiled, the number of samples depends upon the volume of material. As with backfill material, the guidelines provided in the *Guidelines for Acceptance of Solid Waste to Landfill* (DEP, 2001) can be utilised in determining the number of samples required.

8. GLOSSARY

Analyte	Refers to any chemical compound, element or other parameter as a subject for analysis.
ANZECC	Australian and New Zealand Environment and Conservation Council.
Aquifer	Rock or sediment in a geological formation, or group of formations, or part of a formation which is capable of being permeated permanently or intermittently and can thereby transmit water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
Assessment	Study of a site to determine possible and actual contaminants. May involve a desktop review of the site and may also include the collection and analysis of soil, groundwater or sediment samples.
Assessment Levels	Guideline concentrations of contaminants adopted by the DEP to use as a comparison against which to assess the presence and severity of contamination at a site.
Background Concentrations	Naturally occurring ambient concentrations in the local areas of a site.
Beneficial Use	The use of the environment, or of any portion thereof, which is – (a) conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment; or (b) identified and declared under Section 35(2) of the Environmental Protection Act 1986 (as amended) to be a beneficial use to be protected under an approved policy.
Bioavailability	Availability of contaminants in a form in which organisms or biota can assimilate contaminants e.g. contaminants being in a dissolved state or capable of being solubilised once ingested.
Bore	A hole drilled into an aquifer for the purpose of monitoring or extracting groundwater. Another common term is ‘well’.
BTEX	Benzene, Toluene, Ethylbenzene, Xylene.

Clean Fill	Material that will have no harmful effects on the environment and which consists of rocks or soil arising from the excavation of undisturbed material. For material not from a “clean excavation”, it must be validated to have contaminants below Ecological Investigation Levels.
Competent Professional	Possessing the skills, knowledge, experience, and judgement to perform the assigned tasks or activities satisfactorily.
Composite Sample	The bulking and thorough mixing of equal quantities of soil samples collected from more than one sample location to form a single soil sample for chemical analysis.
Contaminant	A substance which has the potential to present a risk of harm to human health or any environmental value.
Contaminant Rebound	Occurs when residual non-aqueous phase liquid (NAPL), sorbed or otherwise, immobilised contaminants, are re-dissolved into the groundwater.
Contaminated	In relation to land or underground water, means that a substance is present in, on or under that land or in that underground water, at a concentration that presents, or has the potential to present, a risk of harm to human health or any environmental value.
Data Quality Objective (DQO)	Qualitative and quantitative statements which specify the quality of the data required.
Dense Non-Aqueous Phase Liquid (DNAPL)	Non-aqueous substances which have an average density greater than water (specific gravity greater than 1) and therefore generally sink in water.
DEP	Department of Environmental Protection.
Detailed Site Investigation (DSI)	An investigation which confirms and delineates potential or actual contamination through a comprehensive sampling program.
Development (of bores)	The removal of fines (including drilling mud) from the aquifer immediately surrounding the bore and creating a filter zone around the bore that prevents further movement of aquifer particles into the bore.
Diffuse Source	Widespread sources of contamination such as the contents of landfill sites, residential areas or large industrial complexes containing a number of point sources.

DMPR	Department of Mineral and Petroleam Resources
Ecosystem	Unit including a community of organisms, the physical and chemical environment of that community, and all the interactions among those organisms and between the organisms and their environment.
EIL$_{soil}$	Ecological Investigation Level. EILs for soil is the concentration of a contaminant below which adverse impacts upon site-specific ecological values are unlikely to occur.
Environmental Value	(a) beneficial use; or (b) an ecosystem health condition. Which requires protection from activities which may degrade, impair or destroy it.
FID	Flame Ionisation Detector.
GROUNDWATER (ALSO UNDERGROUND WATER)	All waters occurring below the land surface.
HIL$_{soil}$	Health Investigation Levels. HILs are utilised to assess contamination where: (a) there is no adverse impact, or little potential for any adverse impact, to the environment, or the environmental value or beneficial use of an environmental receptor; and therefore (b) the adverse impacts arising from contamination at a site are to human health only.
Hydraulic Gradient	The change in the static head (of groundwater) per unit of distance in a given direction.
Hydrogeology	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Interim Sediment Quality Guidelines-Low (ISQG-Low)	Probable-effects concentrations below which biological effects would rarely occur.
Interim Sediment Quality Guidelines-High (ISQG-High)	Probable-effects concentrations below which biological effects would possibly occur. Concentrations at or above the ISQG-High represent a probable-effects range within which effects would be expected to frequently occur.
Investigation Levels	The concentration of a contaminant above which further investigation, evaluation and possibly remediation will be required.

Landfill	In relation to the legal disposal of contaminated material, landfill means a site used for disposal of solid material by burial in the ground that is licensed as a landfill under the *Environmental Protection Act 1986.*
Light Non-Aqueous Phase Liquid (LNAPL)	Non-aqueous substances which have an average density less than water (specific gravity of less than 1) and therefore generally float on water, e.g. petrol.
NATA	National Association of Testing Authorities.
Natural Attenuation	Reliance on natural processes, including various physical, chemical, or biological processes, that, under favourable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil, sediment or groundwater. These *in situ* processes include biodegradation, dispersion, dilution, sorption, volatilisation, chemical or biological stabilisation, transformation, or destruction of contaminants.
NEPC	National Environment Protection Council.
NEPM	National Environment Protection Measure.
NHMRC	National Health and Medical Research Council.
PID	Photoionisation Detector.
Point Source	Localised source of contamination such as storage tanks, pumps and drums.
Practitioners	Suitably qualified professionals with experience in environmental investigations and management.
Preliminary Site Investigation (PSI)	An investigation consisting of a desktop study, a detailed site inspection and, where appropriate, limited sampling. The preliminary site investigation should be of such scope as to be sufficient to indicate whether contamination is present or likely to be present and to determine whether a detailed site investigation should be conducted. Also to provide information for designing a DSI.
Public Drinking Water Source Area (PDWSA)	An area allocated for the collection/abstraction of water for public drinking water supply.

Receptor	The entity that may be adversely affected by contact with or exposure to a contaminant of concern.
Remediation	Action taken to eliminate, limit, correct, counteract, mitigate or remove any contaminant or the negative effects on the environment or human health of any contaminant.
Residual/Remaining Soil/Groundwater	Soil/groundwater remaining after contaminated soil/groundwater has been removed.
Response Level	Concentration of a contaminant at a specific site based on a site assessment for which some form of response is required, to provide an adequate margin of safety to protect public health and/or the environment.
Risk Assessment	Process of estimating the potential impact of a chemical, biological or physical agent on humans, plants, animals and the ecology.
Sample Pattern	The location of sampling points within a sampling area.
SAP	Sampling and Analysis Program.
Saturated Zone	The zone within an aquifer in which all the pores and rock fractures are filled with water.
Sediment	Loose particles of sand, clay, silt and other substances that settle at the bottom of a body of water. Sediment can derive from the erosion of soil or from the decomposition of plants and animals.
Separate Phase Hydrocarbons (also referred to as Phase-Separated Hydrocarbons)	Differences in the physical and chemical properties of water and Non-Aqueous Phase Liquids (NAPLs) results in a physical interface between the liquids, which prevents the liquids from mixing.
Site	An area of land or underground water.

Underground Storage Tank (UST)	A tank that: a) is currently, or has historically been used for the storage of environmentally hazardous substances such as, but not limited to, petroleum products, acids and alkalis; and b) is fully or partially buried.
Underground Water Pollution Control Area (UWPCA)	An area gazetted under the *Metropolitan Water Supply and Drainage Act 1909* to protect groundwater resources used for public drinking water supply. Within these areas restrictions apply to activities which may pollute the groundwater.
Validation	The process of demonstrating that a site has been remediated successfully. Involves the collection and analysis of samples to demonstrate that contaminant concentrations are below acceptable limits and do not pose a risk to human health or the environment.
Watertable	The surface of an unconfined aquifer or confining bed at which the pore water pressure is atmospheric. It can be measured by installing groundwater bores into the zone of saturation and measuring the water level in those bores.
Water Reserve	An area gazetted under the *Country Areas Water Supply Act 1947* to protect groundwater resources used for public drinking water supply. Within these areas restrictions apply to activities which may pollute the groundwater.
Well	Refer to Bore.
WRC	Water and Rivers Commission.

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APPENDIX A

SAMPLING PATTERNS

APPENDIX A. SAMPLING PATTERNS

Judgemental Sampling

Sampling is localised based on knowledge of known or probable distribution, or location of contamination at a site. A high level of confidence in the reliability of information about the site is required and the information needs to reflect the current state of the site.

Stratified Sampling

The site is divided into sub-areas according to one or more of the following:

(i) geological or geographical features;
(ii) spatial distribution of the contamination;
(iii) former usage pattern of the site;
(iv) intended future use of the sub-area; and
(v) any other common factor not listed.

Once divided, each sub-area should be considered as an individual site and different sampling patterns and sampling densities can be applied to each sub-area.

This pattern is the most appropriate approach for investigating large sites with complex contaminant distributions.

Systematic Sampling

Sampling points are regularly spaced using a grid pattern. This method is statistically unbiased, provided the coordinates of the initial sampling point are determined randomly.

Random Sampling

Sampling points are generated using a random number generator (as available on most scientific calculators). This method is statistically unbiased, however sampling points can cluster together, hence it is not the most effective method for evaluating areas of concern. Where this method is used, a surveyed reference point should be established from which all sample points should have a measured bearing and distance. In general, this method has limited use in contaminated site investigations.

Stratified Random Sampling

Involves dividing the site into areas and randomly sampling within each area. This method allows large areas of land to sampled at lower sample densities.

APPENDIX B

NUMBER OF SAMPLE LOCATIONS REQUIRED FOR HOT SPOT DETECTION

APPENDIX B. NUMBER OF SAMPLING LOCATIONS REQUIRED FOR HOT SPOT DETECTION

This Appendix has been modified from *AS 4482.1-1997*.

B1. SCOPE

The method presented here is based on detecting circular hot spots with 95% confidence using a square grid sampling pattern. To detect hot spots of other shapes, at other confidence levels or by using other sampling patterns, the following references should be consulted:

(a) GILBERT, R.O (1987) *Statistical methods for environmental pollution monitoring,* Chapter 10. Van Nostrand Reinhold: New York.
(b) FERGUSON, C.C. (1992) The statistical basis for spatial sampling of contaminated land. *Ground Engineering,* pp 25, 34-38.
(c) NSW EPA, *Contaminated Sites Sampling Design Guidelines,* September 1995.

B2. CALCULATIONS

B2.1 GRID SIZE

The grid size, G, should be calculated using Equation B1:

$$\mathbf{G} = \mathbf{R / 0.59} \qquad \ldots \text{(B1)}$$

where: G = grid size of the sampling plan, in metres
R = radius of the smallest hot spot that the sampling intends to detect, in metres
0.59 = factor derived from 95% detection probability, assuming circular hot spots.

B2.2 NUMBER OF SAMPLING POINTS

The number of sampling points n should then be calculated from Equation B2:

$$\mathbf{n} = \mathbf{A / G^2} \qquad \ldots \text{(B2)}$$

where: A = area to be sampled, in square metres
G = grid size of the sampling pattern, from Step B2.1, in metres

B3. PROCEDURE

The procedure should be as follows:

(a) Determine the radius of the hot spot, R, that needs to be detected.
(b) Calculate the grid size, G, from Equation B1.
(c) Determine the number of sampling points required, n, from Equation B2.

APPENDIX C

MINIMUM SAMPLING POINTS REQUIRED FOR SITE CHARACTERISATION BASED ON DETECTION OF CIRCULAR HOT SPOTS USING SYSTEMATIC SAMPLING PATTERN

APPENDIX C. MINIMUM SAMPLING POINTS REQUIRED FOR SITE CHARACTERISATION BASED ON DETECTION OF CIRCULAR HOT SPOTS USING SYSTEMATIC GRID SAMPLING PATTERN

This table has been modified from *Contaminated Sites Sampling Design Guidelines* (NSW EPA, 1995)

AREA OF THE SITE AND/OR EXCAVATIONS ha (m^2)	NUMBER OF SAMPLING POINTS RECOMMENDED	EQUIVALENT SAMPLING DENSITY (POINTS/ha)	DIAMETER OF THE HOTSPOT THAT CAN BE DETECTED WITH 95% CONFIDENCE (m)	GRID SIZE (m)
0.05 (500)	5	100.0	11.8	9.5
0.1 (1000)	6	60.0	15.2	12.9
0.2 (2000)	7	35.0	19.9	16.9
0.3 (3000)	9	30.0	21.5	18.2
0.4 (4000)	11	27.5	22.5	19.1
0.5 (5000)	13	26.0	23.1	19.6
0.6 (6000)	15	25.0	23.6	20
0.7 (7000)	17	24.3	23.9	20.3
0.8 (8000)	19	23.8	24.2	20.5
0.9 (9000)	20	22.2	25.0	21.2
1.0 (10 000)	21	21.0	25.7	21.8
1.5 (15 000)	25	16.7	28.9	24.5
2.0 (20 000)	30	15.0	30.5	25.4
2.5 (25 000)	35	14.0	31.5	26.7
3.0 (30 000)	40	13.3	32.4	27.4
3.5 (35 000)	45	12.9	32.9	27.9
4.0 (40 000)	50	12.5	33.4	28.3
4.5 (45 000)	52	11.6	34.6	29.3
5.0 (50 000)	55	11.0	35.6	30.1

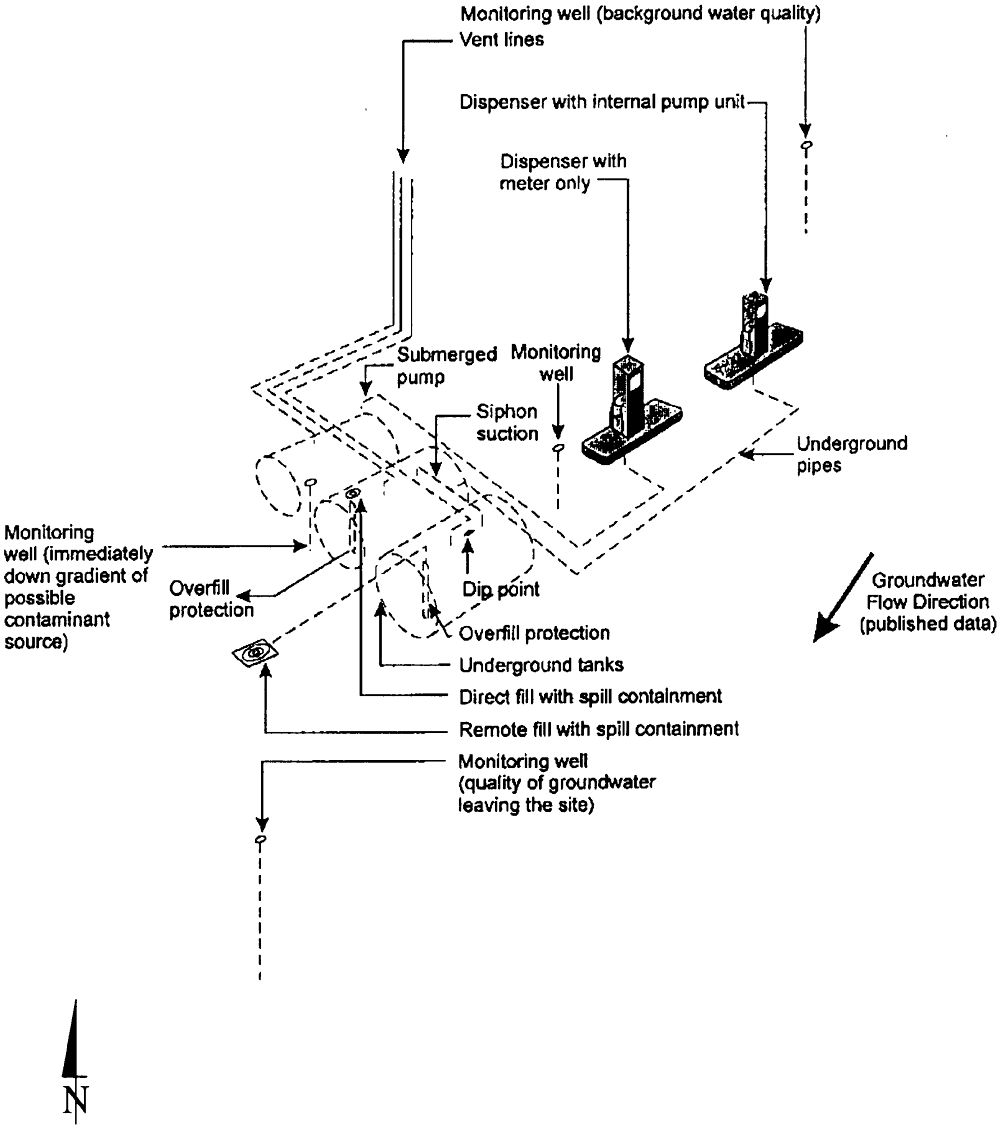
Notes: 1 **The provision in this table of the number of sampling points does not imply that minimum sampling is good practice for a given site. The investigator should be prepared to justify the appropriateness of applying this table or any other sampling rationale.**

2 No guidance is provided for sites larger than five hectares (50 000 m^2). Such sites are usually subdivided into smaller areas for more effective sampling.

APPENDIX D

TYPICAL UNDERGROUND STORAGE TANK (UST) INFRASTRUCTURE AND GROUNDWATER MONITORING BORE LOCATIONS

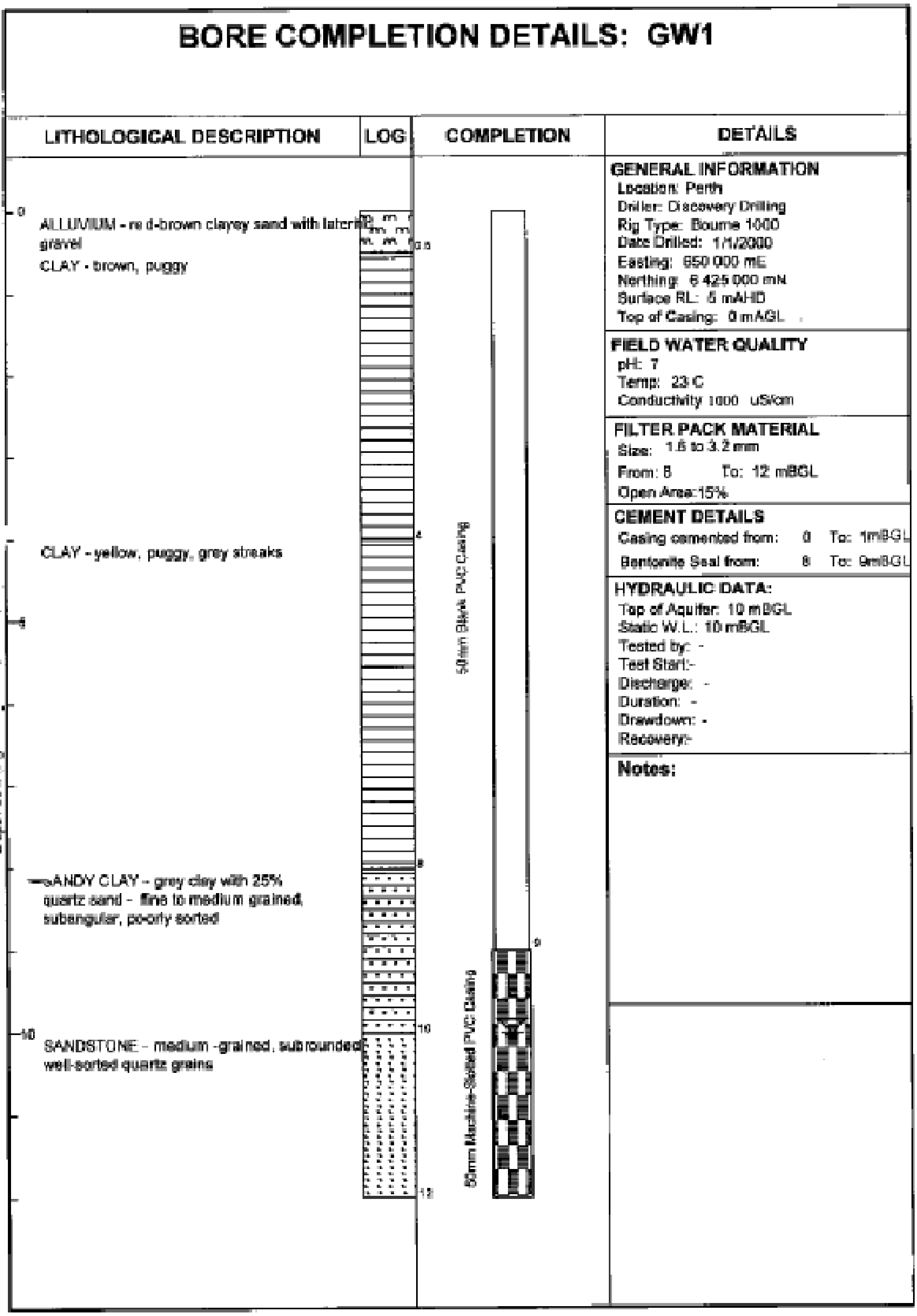
APPENDIX D. TYPICAL UST SITE INFRASTRUCTURE & GROUNDWATER MONITORING BORE LOCATIONS.



APPENDIX E

BORE CONSTRUCTION DETAILS

APPENDIX E. BORE CONSTRUCTION DETAILS



BORE COMPLETION DETAILS: GW1

LITHOLOGICAL DESCRIPTION

ALLUVIUM - red-brown clayey sand with lateri gravel

CLAY - brown, puggy

CLAY - yellow, puggy, grey streaks

SANDY CLAY - grey clay with 25% quartz sand - fine to medium grained, subangular, poorly sorted

SANDSTONE - medium -grained, subrounded well-sorted quartz grains

DETAILS

GENERAL INFORMATION

Location: Perth
Driller: Discovery Drilling
Rig Type: Bourne 1000
Date Drilled: 1/1/2000
Easting: 650 000 mE
Northing: 6 425 000 mN
Surface RL: 5 mAHD
Top of Casing: 0 mAGL

FIELD WATER QUALITY

pH: 7
Temp: 23 C
Conductivity 1000 uS/cm

FILTER PACK MATERIAL

Size: 1.6 to 3.2 mm
From: 8 To: 12 mBGL
Open Area: 15%

CEMENT DETAILS

Casing cemented from: 0 To: 1mBGL
Bentonite Seal from: 8 To: 9mBGL

HYDRAULIC DATA:

Top of Aquifer: 10 mBGL
Static W.L.: 10 mBGL
Tested by: -
Test Start: -
Discharge: -
Duration: -
Drawdown: -
Recovery: -

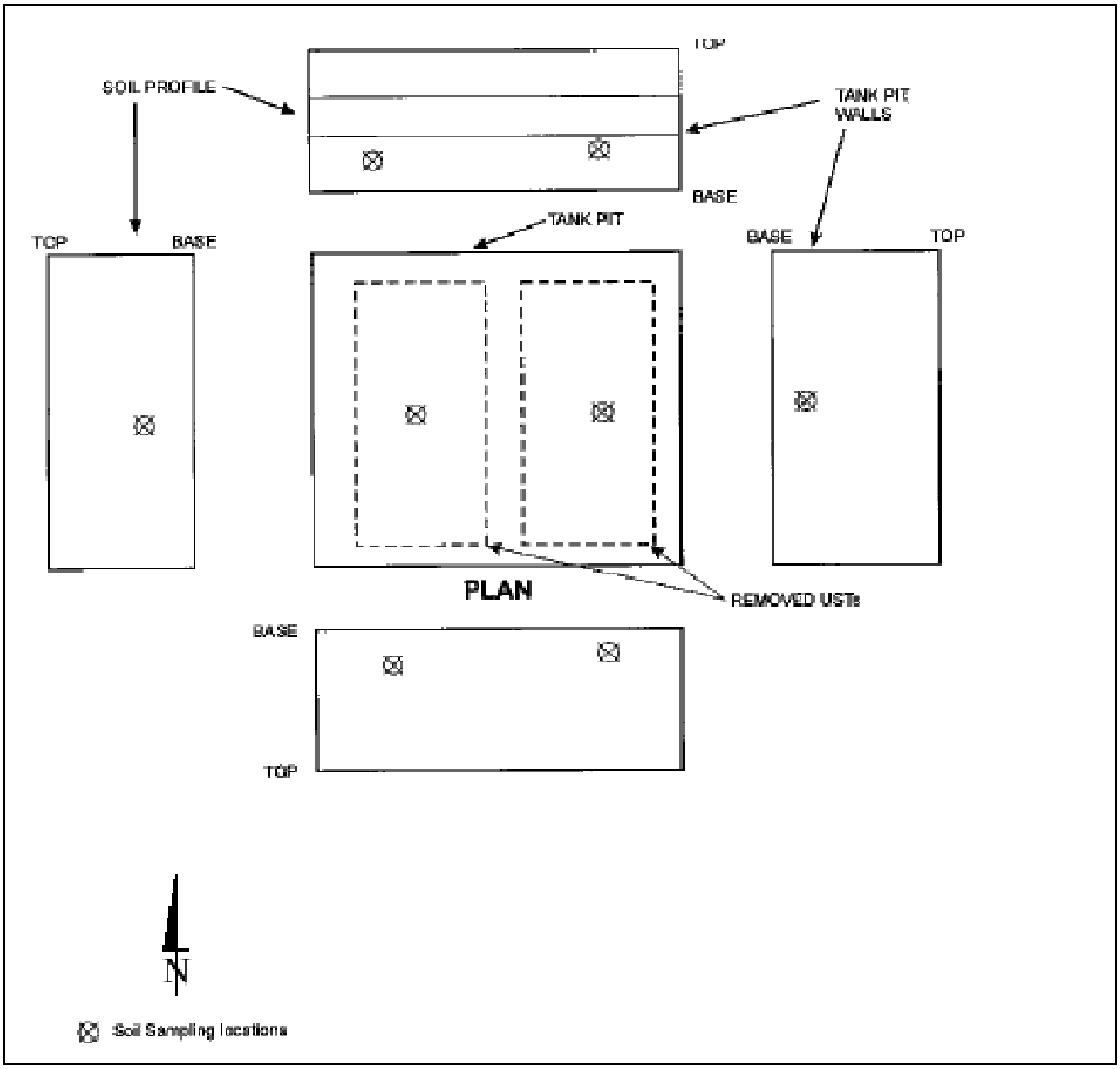
Notes:

APPENDIX F

TANK PIT VALIDATION: TYPICAL SOIL SAMPLING LOCATIONS

APPENDIX F.

TANK PIT VALIDATION: TYPICAL SOIL SAMPLING LOCATIONS.



APPENDIX B

Sampling Questionnaire

Proposed Sampling Analysis Plan Questionnaire and Survey

Date						
Location						
Approximate distance from Esperance Port						
GPS coordinates at front door	LAT					
	LONG					
Name of Family						
Persons conducting the walk over and communication with resident						
Number of occupants						
Age of occupant(s)						
Gender						
Is there a source of lead contamination other than the Esperance Port in the vicinity (e.g. lead smelter, car repairer where paint is stripped, battery breaking yard)?						
Describe land uses in surrounding areas	North					
	South					
	East					
	West					
Time in present home						
Total time in Esperance						
Rent or own						
Construction material of walls	Brick					
	Fibrous cement					
	Tin					
	Other					
Construction material of roof	Tile					
	Fibrous cement					
	Rendered					
	Corrugated iron/colourbond					
	Other					
Other roof features	Is there an air conditioner?					
	If yes where does the water run off?					

	Is there a hot water system?	
Have renovations / demolition been carried out recently?		
Renovation/Demolition	If yes, what were the cleanup procedures and what did the work entail	
	Were carpets or other soft furnishings left uncovered during renovations	
Ceiling voids	Is there a ceiling space	
	Has any work been carried out in the roof lately, i.e. termite inspection, storage area.	
	How do you access the ceiling in your house?	
Is there general waste around the house	If yes, this should be described below	
Does the block have areas of bare soil or sandpits		
Are there any pets at the premises	If yes how many and what kind	
	Do they live indoors or outdoors	
Ceiling/wall condition	Good (no deterioration- < 5 years old)	
	Fair (< 15% deterioration)	
	Poor (> 15% deterioration)	
Paint condition	Good (no deterioration- < 5 years old)	
	Fair (< 15% deterioration)	
	Poor (> 15% deterioration)	
Lead paint present inside residence	If lead paint is thought to be present, what is the percentage of deterioration %	
Fireplace present		

Floor coverings	Number of rooms	
	Age	
	Carpet	
	Tiles	
	Wood	
	Other	
Presence of mats at entrances		
Cleaning questions	Does the residence have a vacuum cleaner and does it have a HEPA filter?	
	When was the vacuum cleaner last emptied?	
	Has the vacuum cleaner been used outside the residence?	
	Has the vacuum cleaner been used at another residence?	
	Has the vacuum cleaner been used in a vehicle?	
	Does the vacuum have a bag or is it bagless?	
	If the vacuum has a bag, what material is it made of, (i.e. cloth, plastic)?	
	How often is the residence vacuumed?	
Is there a garage on the premises?	What type?	
Is there a shed on the premises?	What is its use?	
Occupation	What is your occupation?	
	How long?	
	Has any occupant worked at the Port since 2004?	
	If yes, who/how long/occupation?	

Hobbies		
Rainwater tank	Do you have a rainwater tank?	
	Tank construction material and age of tank?	
	Do you drink or have you drunk the water from your tank?	
	Has the rain water been tested?	
	What were the results?	
	Was it part of the UWA study?	
	Have you had your rainwater tank /roof cleaned and the rainwater retested? If so, when?	
	Do you have a first flush device on your tank?	
	Are there lead flashings and/or pipes in the structures?	
	Are there trees overhanging or nearby roof?	

APPENDIX C

Limitations

LIMITATIONS

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