Environmental
Protection Statement

PROPOSED REMEDIATION OF CONTAMINATED SITES ON MORANGUP ROAD TOODYAY

AUGUST 2001

Proponent: Department of Environmental Protection

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Executive Summary

This Environmental Protection Statement (EPS) describes a proposal by the Waste Management Division of the Department of Environmental Protection (DEP) to remediate three contaminated properties, located on Morangup Road in Toodyay.

Between 1963 and 1975 wood tar waste from the State owned and operated Wundowie Charcoal Iron and Steel Industry was dumped on crown land along Morangup Road. Following the sale of the facility in 1976 the sites were subdivided and sold to the public. The presence of the wood tar contamination was not noted until 1992 when contaminated groundwater was discovered on one of the properties.

Extensive investigations into the contamination and its impacts have been performed on the sites since 1997. These studies have established the extent, nature and concentration of the contamination and its health and ecological impacts.

The tar waste material on the three sites has combined with the natural soils and caprock. Over time it has leached into the groundwater on two of the three sites. Analyses of the contamination has shown phenols to be the major contaminant, with very low concentrations of Poly Aromatic Hydrocarbons (PAH) also found.

The concentration of the soil contamination is not considered to be a health risk with all concentrations less than 96mg/kg phenols, with an average concentration of 4.6mg/kg. The Health Investigation Level for phenol in soils is 8, 500mg/kg.

Groundwater contaminated with phenols has been discovered under two properties. The contamination is minor and is not currently considered by the Department of Health to pose a health risk. However, long term monitoring of the contaminated groundwater will continue at six monthly intervals and caveats and restrictions on use will be established if necessary.

Investigations into the wood tar contamination, and consultation with the local community has identified dust as the principal environmental issue. Management of dust during the remediation will be in accordance with the requirements of the Environmental Management Program (EMP). This will include monitoring and the use of action levels approved by the Environmental Protection Authority (EPA), on advice from the Department of Health.

The waste residues in the soil prevent the land being used for its beneficial use because of the hydrophobic nature of the soils and nuisance dust, which can aggravate respiratory problems. The areas of contamination have further potential to affect groundwater, which is heavily utilized in the Morangup area due to the lack of scheme water.

The Western Australian government has committed to remediating the three sites and returning the land to a beneficial rural use. This document describes a remediation strategy to excavate and dispose of contaminated soils.

The preferred remediation option is as follows:

1) Remove top 250mm of contaminated soils;
2) Excavate all contaminated soil above 9mg/kg of total phenols;
3) Dispose removed soils (approximately 11, 000m^3) at Colebatch Road Class II landfill facility or other approved Class I or II landfill facility. The disposal location will be confirmed in the EMP.
4) Seal any contaminated caprock;
5) Backfill excavated areas;
6) Rehabilitate sites.

The remediation of the sites will be carried out in a safe manner to ensure risks to workers, the public and the environment are within acceptable limits. To ensure all potential risks are managed appropriately, an EMP will be prepared and implemented. Preparation of the EMP will be undertaken prior to the commencement of site works and will be subject to approval by the EPA. The EMP will include, but not be limited to, management techniques to control dust, noise and health and safety.

A suitably qualified contractor, who will be selected from a tender review, will perform the site remediation. The successful contractor will be required to remediate the sites in accordance with commitments outlined in this EPS. Compliance with these commitments will be in the form of Ministerial Conditions, which will be audited by an EPA appointed auditor.

The DEP considers that this proposal will have a positive impact on the sites, as it will allow owners to utilize their properties for agricultural purposes and prevent the further contamination of the groundwater.

1. INTRODUCTION

1.1 Background

Between 1948 and 1975 the State Government owned and operated the Wundowie Charcoal Iron and Steel Industry, near Northam, which distilled wood to produce charcoal for use in the iron and steel works. A by-product of the distilling process was a tar like waste containing phenolic compounds, Poly Aromatic Hydrocarbons (PAH) and hydrocarbons.

Between 1963 and 1975 this waste by-product was dumped on vacant Crown land in the Morangup area. The wood tar waste dumpsites were apparently not bunded in any way and the wood tar wastes flowed down gradient across the natural soil surface. In 1976 the affected land was subdivided and sold to the public.

In 1992, the presence of contaminated groundwater in Morangup was identified when a domestic bore was found to be contaminated with phenolic compounds. Preliminary investigations into the extent of contamination determined that three residential lots contained surface soils contaminated with wood tar residues, and that phenols had been released into the groundwater at two sites.

In early 2000 the State government made available funds of $1.15M to cover the cost of remediating the sites. The Waste Management Division of the DEP subsequently commissioned detailed investigations into the nature and extent of the contamination. Reports on these and earlier investigations form the basis for this proposal. The investigation reports are publicly available at the Midland, Toodyay, Northam, Battye and DEP libraries.

1.2 Proponent

The proponent for the remediation of the contaminated sites at Morangup is the DEP.

1.3 Need for proposal

Investigations by the DEP have shown that remedial works are required at the sites for the following reasons:

1) The surface soils of contaminated areas are highly hydrophobic (non-wetting), resulting in limited penetration of rainfall into the root zone. Consequently the contaminated areas do not readily support plant growth.
2) When disturbed, the contaminated soils are subject to substantial generation of fine dust. The Department of Health has advised that although the levels of contaminants in the dust are not a health risk, the dust itself may aggravate respiratory problems in nearby residents.
3) Contaminated soil may continue to contaminate the groundwater.

1.4 Timing

It is anticipated the remediation of the contaminated sites will begin in September 2001, with site works completed within thirteen weeks. In order to control dust, soil

wetting agents or other products will be applied to the sites four weeks and two weeks before earthworks begin and during remediation works as necessary. Scheduling of the remedial works during winter will aid in dust management.

1.5 Environmental Approval Process

The Chairman of the EPA was notified of the proposal in April 2001. The EPA Chairman then indicated that, based on the outcomes of investigations to date and the extent of previous and proposed public consultation, a proposal to remediate the contaminated sites at Morangup would be likely to be assessed at the level of EPS.

This EPS is designed to fulfill the requirements of the EPS level of assessment, including public consultation of the proposed remediation. The EPS process is illustrated in Figure 1.

1.6 Regulatory Requirements

The key environmental legislation applying to the remediation of the Morangup contaminated sites is the *Environmental Protection Act 1986.* This Act contains provisions for evaluating the environmental impacts of projects and allows the EPA to request a proponent to prepare documentation for evaluation through the environmental approval process. Additionally the Act provides powers for the prevention, control and abatement of discharges into, and polluting of, the environment.

Other legislation which are applicable to the remediation are:

- Occupational, Safety and Health Act 1984
- Environmental Protection (Noise) Regulations
- Road Traffic Act 1974
- Bush Fires Act 1954
- Health Act 1911
- Environmental Protection (Controlled Waste) Regulations 2001
- Soil and Land Conservation Act 1945

2. CONTAMINATED SITES

2.1 Location

The three contaminated sites are on private properties located on the west side of Morangup Road, approximately 25 km southwest of Toodyay. They are depicted in Figure 2 and are listed below:

Site	Lot Number	Area of Property	Approximate Area of Contamination
A	3	100, 000 m^2	9, 700 m^2
B	81	100, 000 m^2	13, 700 m^2
C	11	94, 000 m^2	11, 400 m^2

A small amount of contamination from Site C (appropriately 700m^2) has entered Lot 12. This contamination will be removed as part of Site C's remediation.

2.2 Land Use and Zoning

The three contaminated properties are currently zoned as 'special rural' by the Shire of Toodyay under Town Planning Scheme 3. This zoning allows a variety of land uses including minimal agricultural uses and residential purposes.

Site A is a residential property which has been cleared and a permanent dwelling established. It is not currently used for agricultural purposes, but the owner has expressed a desire to plant crops or graze some livestock on the property.

Site B is privately owned, uninhabited and covered in patchy native vegetation. The owner has generally agreed with the proposal to re-establish native vegetation on the disturbed areas.

Site C is used for residential and agricultural purposes. The property contains a permanent dwelling, large shed, and a small number of livestock. The owner plans to grow sandalwood crops on the property.

3. DESCRIPTION OF THE ENVIRONMENT

3.1 Physical

3.1.1 Rainfall and Evaporation

The contaminated sites are located in a temperate weather zone, experiencing dry hot summers and moderately wet winters. An average rainfall of approximately 400-600 mm is expected each year, the majority of which is received during the winter months (June to August).

There are no evaporation records for the Toodyay area. However, it is expected than evaporation will be less than for Perth Airport, which has a daily evaporation rate of 3.6mm in September and 5.3mm in October. The annual evaporation rate is 19.3mm (Bureau of Meteorology website).

3.1.2 Wind

No wind data is collected in the Shire of Toodyay, however, data is collected by the Bureau of Meteorology for the Northam region. The average wind speed for the year is 4.6 knots in the morning (recorded at 9am) and 6.2 knots in the afternoon (recorded at 3pm). The wind is generally stronger in early summer, with the windiest month being November with 6.5 knots in the morning and 7.3 knots in the afternoon. Wind in winter tends to be less defined.

During the months of September and October when the remedial works are planned the average wind speed and direction are as follows (Bureau of Meteorology, personal conversation):

		September	***October***
Wind speed:	Morning	4.2 knots	5.9 knots
	Afternoon	6.5 knots	7.0 knots
Main wind direction:	Morning	North-westerly (15%)	South-easterly (21%)
	Afternoon	Westerly (22%)	Westerly (22%)

3.1.3 Geology

The Morangup region is underlain by Achaean granitic rocks which have been intruded by dolerite dykes, and weathered to a 10 to 50m thick profile. This weathered profile consists of, in order of increasing depth, up to 10 metres of ferricrete (a mixture of sand, pisolitic laterite gravel and massive hard laterite caprock), a mottled ferruginous clay zone, consisting of clay and sand and a white sandy clay zone overlying fresh granite or dolerite bedrock.

3.1.4 Soils

The soil on site A is primarily clayey sand with minor pisolitic gravel. However, the soils on site B and C are mainly pisolitic gravels with minor amounts of sand and clay.

3.1.5 Hydrogeology

Groundwater in the area occurs on a permanent basis within the weathered rock profile and possibly within fractures in the fresh bedrock. The groundwater flow in the low permeability permanent aquifer is slow and related to regional topography.

There are a number of private groundwater bores in the immediate area equipped with low capacity pumps supplying water for both drinking purposes and small scale crop irrigation systems. The majority of residents in the area use bore water for irrigation or stock watering purposes only and collect rainwater for drinking and other household purposes. Scheme water is not available in the area.

Previous bore census investigations have shown the groundwater in the area is fresh and potable with a salinity range from 280 to 420mg/L Total Dissolved Salts with individual bore yields of about $50m^3$ per day (Geological Survey of Western Australia, 1992).

3.1.6 Hydrology

Specific details of the hydrology of each site are detailed below;

Site A: The depth to groundwater ranges from 4.5m to 8.3m below surface. The water table contour indicates flow to the northeast towards Morangup Brook. At the site the hydraulic gradient is low at about 0.004. The aquifer is developed within sandy clays derived from weathering of mafic rich Arachean rocks. Groundwater recharge will occur locally by direct rainfall infiltration through surface clayey sand and gravels, and in turn through indurated massive laterite caprock. The low hydraulic gradient is likely to result from the location of the site near a groundwater flow system divide.

Site B: The depth to groundwater is an average of 10.5m below the surface. Water table contours indicate flow to the west- southwest towards a creek line. At the site the hydraulic gradient is moderate at about 0.03. The aquifer is developed within sandy clays derived from weathering of mafic rich Archean rocks. Bedrock occurs at relatively shallow depth and was intersected at 11.7m.

Site C: The depth to groundwater ranges from 4.3m below surface on the lower slopes of the site, to 16.1m on the more elevated area of the site. Water table contours indicate flow to the west-northwest towards a nearby creek line 400m west of Site C. At the site the hydraulic gradient is moderate at about 0.04. The aquifer is developed within sandy clays derived from weathering of mafic rich Archean rocks. Bedrock occurs at relatively shallow depth and was intersected in several of the bores at about 14m to 19m depth below surface.

3.2 Ecological Characteristics

3.2.1 Vegetation and Flora

The Toodyay region was settled in the late 1830s and has been extensively developed, primarily for agricultural purposes, removing much of the native vegetation and introducing agricultural species. Two of the affected sites on Morangup Road have

been significantly cleared for cropping and livestock purposes, but Site B is covered in patchy vegetation.

An officer from the DEP Evaluation Division inspected the properties on 8 November 2000, and determined the indigenous vegetation type of the region to be Dwellingup Yalanbee and Hester/Complex in low to medium rainfall. It was determined that the condition of most of the vegetation on the sites was not ecologically self-sustaining, its ecological health being compromised by the soil contamination.

The remediation of the properties will involve the removal of small areas of native vegetation. Under the *Soil and Land Conservation Act 1945* notification must be given if the clearing of native vegetation will lead to a change in the land use, or if its area is greater than one hectare. The Evaluation Division has informed the Waste Management Division that the vegetation observed on the properties in Morangup is not considered "notifiable' because of its diminished ecological health and because the areas of notifiable vegetation are less than one hectare (Appendix 1).

Considering the sites will be rehabilitated with native species and the poor condition of the vegetation, it is unlikely the removal of vegetation in the contaminated areas during the remediation will impact adversely on the environment, conservation of native vegetation or the maintenance of biodiversity.

3.2.2 Fauna

The natural ecosystems on sites A and C have long been disturbed and all three blocks are situated in a developed, primarily agricultural area. As such it is unlikely that remediation activities would adversely impact any native fauna.

Site B is the only site which remains primarily undisturbed and may contain some native fauna. However, the scale of the site works and short term nature of the disturbance mean the remediation is unlikely to have any adverse effect on fauna.

3.3 Social

People have settled in the Morangup area to enjoy a country lifestyle, but with the conveniences of city living still relatively close by. Many of the properties in the area are only inhabited intermittently by people who live in Perth and commute between the property and their usual residence. Some properties are permanently inhabited and used for small-scale agricultural purposes.

3.3.1 Surrounding Land Use

The properties on Morangup Road and the surrounding streets are zoned as 'special rural' under the Town Planning Scheme 3. They are primarily developed properties with residential dwellings and "hobby" farms with animals grazing and residents growing produce.

Properties immediately surrounding the contaminated sites have vineyards, orchards, livestock and sandalwood crops on them. At the furthest end of Morangup Road (from Toodyay Road) clay mining is undertaken. This operation is operating under a special

approval, which allows excavation industries on land zoned as rural. Additionally the Shire of Toodyay has indicated that a rezoning proposal is currently being drafted to change the zoning on the corner of Morangup Road and Toodyay Road to commercial, and build a tavern and shops. This proposal is at least two years away and will not impact on the remediation.

3.3.2 Population

The Shire of Toodyay has a population of 3, 825, of which approximately 900 people reside in the locality of Morangup (Shire of Toodyay, personal conversation).

Although only four properties are contaminated, one of which is not inhabited, seven other properties lie within close proximity and must be considered in any remediation strategy. These properties are Lots 2 and 4 Morangup Road, Lots 80, 82, 83 and 104 McKnoe Drive and Lot 23 Louisa Circle. Only Lots 82 Morangup Road and 23 Louisa Circle are permanently inhabited (Figure 2).

3.4 Contamination

3.4.1 Soil

Six investigations into the soil contamination on Morangup Road have been undertaken since 1997 (CMPS&F, *Phase 2 Report, Morangup Road, Toodyay,* 1997; Dames and Moore, *Assessment of Remediation Options for Contaminated Land on Morangup Road*, 2000; Thorpe, *Advice on a Soil Characterisation Program for Contaminated Sites near Morangup Road,* 2000; Sinclair Knight Merz, *Dust Characterisation and Soil Wetting Program for Contaminated Sites near Morangup Road,* 2001; Thorpe *Soil Characterisation and Testing Program for Contaminated Sites near Morangup Road, Toodyay, Western Australia,* 2001; Sinclair Knight Merz *Risk Assessment of Contaminated Sites near Morangup Road, Toodyay*, 2001). The outline below is based on the findings of these reports.

The wood tar waste, originally in a liquid form, has spread across the properties along the natural contours of the land (Figures 3, 4, and 5). It has combined with the natural soil in varying degrees ranging from complete impregnation of soil pore space to a dark grey staining of soil particles. Penetration is irregular and often lobed due to differences in soil permeability and variations in the viscosity of different batches of wood tar. On two properties the contamination has extended into the caprock below and appears as either cavity infill or the coating of discrete open cavities.

The weathered contaminated soils are extremely hydrophobic and produce dust when disturbed even after extensive wetting. This dust contains the same contaminants as the soil but generally in higher concentrations.

The wood tar waste is thought to have contained phenolic compounds, Poly Aromatic Hydrocarbons and total hydrocarbons. However, sampling has indicated that phenols are the only component remaining in any significant concentration in the soil or caprock. The highest concentration of contamination is predominantly located within the top 250 mm of soil, although high concentrations have been discovered within the caprock. Table 1 provides detail on the vertical distribution of the contamination.

The contaminated soil and caprock have been assessed against the Health and Ecological Investigation Levels outlined in the *Contaminated Site Assessment Criteria (draft), Department of Environmental Protection, 2000.* When reached, these levels are intended to prompt an appropriate site-specific assessment to determine a relevant clean up criteria.

All the soil and caprock contamination is significantly below the Health Investigation Level (HIL) for phenol of 8, 500mg/kg, indicating that no health risk is posed by the contamination. However, 61% of the contamination is above the Ecological Investigation Level (EIL) of 1mg/kg. As such a risk assessment (Appendix 2) was completed to establish a relevant clean up criteria which is protective of the Morangup environment. This clean up criteria is 9mg/kg of total phenols.

This clean up criteria has been assessed and agreed to by the Water and Rivers Commission and Health Department of Western Australia (Appendices 3 and 4).

Table 1 Quantities and Composition of Wood-tar Contaminated Soil [1]

	Area of contamination	Average depth of contamination	Average conc. of phenols (mg/kg)	Average concentration of phenols (mg/kg)			% of contamination over EIL (1mg/kg) [2]	% of contamination above HIL (8500mg/kg) [3]	% of contamination above 9mg/kg
				Top 250 mm	250 mm to caprock	Caprock			
Site A	9, 721m2	0.29m	1.78 mg/kg	3.8 mg/kg	0.5 mg/kg	N/a	37% of samples	0%	2.8% of samples
Site B	13, 685m2	0.41m	3.73 mg/kg	4.7 mg/kg	1.8 mg/kg	12.0 mg/kg	56% of samples	0%	6.6% of samples
Site C	12, 130m2	0.62m	4.10 mg/kg	5.18 mg/kg	2.3 mg/kg	6.9 mg/kg	77% of samples	0%	7% of samples
Total	35, 536m2	0.44m	3.48 mg/kg	4.7 mg/kg	1.7 mg/kg	8.1 mg/kg	61.3% of samples	0%	6% of samples

Notes:

1. Thorpe Groundwater and Environmental Services, *Soil Characterisation and Testing Program for Contaminated Sites near Morangup Road, Toodyay, Western Australia*, February 2001.

2. EIL- Ecological Investigation Level

3. HIL- Health Investigation Level

3.4.2 Groundwater

In July 2000, a major investigation was commissioned into the extent of wood tar contamination in the groundwater at Morangup (*Thorpe Groundwater and Environmental Services, Investigation of Groundwater Contamination at Morangup Road, Toodyay, Western Australia, 2000*). In November 2000 six monthly monitoring of the groundwater was initiated. The outline below is based on these findings.

Wood tar contamination on two properties has percolated through the soil into the groundwater table. The extent of the resulting plumes has been estimated in Figures 6 and 7. The plume under Site A is believed to have reached onto the neighbouring property, while the plume under Site C has reached onto two neighbouring properties and is heading towards a local creek. No groundwater contamination has been detected on Site B.

The beneficial use of the groundwater in the Morangup area is for irrigation, stock watering and occasionally drinking. As such the monitoring results have been assessed against available criteria for these uses. The results have also been assessed against the freshwater ecosystem criteria to ensure protection of the nearby creek.

The groundwater plumes are being monitored for phenols, Poly Aromatic Hydrocarbons (PAH), BTEX (benzene, toluene, ethylbenzene and xylene) and Total Petroleum Hydrocarbons (TPH), as these are the chemicals associated with wood tar waste. No PAH or BTEX have been detected in any of the samples, and the only TPHs found have been low levels of mid chain hydrocarbons, which are indicative of phenol contamination. Therefore while monitoring of PAH, BTEX and TPH will continue until November 2001 to allow for seasonal fluctuations, it can be concluded that only phenols have contaminated the groundwater.

The *Australian Drinking Water Guidelines, NHMRC/ARMCANZ, 1996*, have not set a drinking water value for phenol or total phenols. As such the Health Department has suggested that the criteria for the most toxic chlorophenol be used as a guideline value for a safe level of total phenols in drinking water. Therefore the groundwater has been assessed against 20ug/L, the criterion for 2, 4, 5-trichlorophenol (Table 2). This value is very conservative given that the United States Environmental Protection Agency has set a preliminary remediation goal of 22, 000ug/L for phenol itself in tap water.

The groundwater has been analysed for total phenols, phenol, and four other types of phenols, which have drinking water criteria specified in the *Australian Drinking Water Guidelines, NHMRC/ARMCANZ, 1996*. Unfortunately the May 2001 results were not analysed for total phenols and therefore this data is absent.

The groundwater samples analysed to date have all shown levels of total phenols and speciated phenols below detection, with the exception of bores A1MB, A2MB, CD1 and CS1. In November 2000 total phenol levels of 30ug/L and 40ug/L were detected in bore A2MB and CD1, respectively. These phenol levels are slightly above the 20ug/L limit set. However, because neither of these bores are used for domestic purposes and both recorded total phenols levels of less than 5ug/L in December 2000, they are not currently considered to pose a health or ecological risk.

High levels of total phenols were detected in bores A1MB and CS1 in November 2001. However when these bores were sampled again in December both had total phenol levels of less than 5ug/L. The cause of this discrepancy is unknown, however, it is important to note that the levels of each phenol sampled, remained the same even when the total phenol level increased. These bores are not used for domestic purposes and will continue to be monitored, with any necessary measures being implemented as required.

No value has been established in Australia for phenols or total phenols in water used for irrigation purposes. However, it is expected that the groundwater, being suitable for drinking, will also be suitable for irrigation.

The *Contaminated Site Assessment Criteria (draft), DEP 2000* has established a criterion of 50ug/L for phenol in freshwater ecosystems. Additionally the *Australian Water Quality Guidelines for Fresh and Marine Waters, ANZECC* has set freshwater criteria for two of the phenols sampled for. All samples of phenol and 2, 4, dichlorophenol are below the specified criteria. However, the criteria for pentachlorophenol is below the detection limit used in the analysis, and therefore we are unable to determine if this criterion is being met. All future monitoring will be analysed using a lower detection limit.

The criteria for total phenols in livestock waters set by the *Contaminated Site Assessment Criteria (draft), DEP 2000*, is 2ug/L. This limit is based on the Australian Water Quality Guideline value for total phenols in raw water and is based on aesthetic considerations rather than toxicity concerns. From the results available no conclusions regarding this criteria can be determined as the detection limit for total phenols has always been higher than the criteria. Future monitoring will use a lower detection limit.

All domestic bores sampled have consistently recorded phenols below the required criteria. The Health Department has stated that, on the information provided, the contamination does not pose a health risk to people living on the properties or drinking the water (Appendix 5).

The contaminated plumes will continue to be monitored by the Water and Rivers Commission on a six monthly basis, and new bores and caveats placed on the land titles as necessary.

3.5 Existing Traffic

Main Roads have provided an average daily traffic volume on Morangup Road for Monday to Friday. This is 208 vehicles per day. Of this amount 165 are cars and the remainder trucks.

Therefore on average 43 trucks, presumably from the clay mining activities located at the far end (away from Toodyay Road) of the road, travel on Morangup Road per day. As such it is unlikely the truck movements required during the remediation will cause any disturbance to, or adverse effects on, the environment or community.

Table 2 **Groundwater Monitoring Results**

Lot / Site	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water criteria (ug/L)*	*Fresh Water* [5] *Criteria (ug/L)*
SITE A						
Domestic	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophenol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
AS2	Total Phenols	<20	<5	Dry	20 [3]	-
	Phenol	<0.10	<1.0		-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0		200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0		20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0		1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0		10 [2]	0.05ug/L [2]
AD2	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	1.3	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
A1MB	Total Phenols	500	<5	-	20 [3]	-
	Phenol	0.50	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]

Lot / Site	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water criteria (ug/L)*	*Fresh Water [5] Criteria (ug/L)*
A2MB	Total Phenols	30	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
SITE B						
B1MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
B2MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
SITE C						
C1MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]

Lot / Site	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water criteria (ug/L)*	*Fresh Water [5] Criteria (ug/L)*
C2MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
C3MB	Total Phenols	<20	<5	Dry	20 [3]	-
	Phenol	<0.10	<1.0		-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0		200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0		20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0		1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0		10 [2]	0.05ug/L [2]
C4MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
C5MB	Total Phenols	<20	<5	Dry	20 [3]	-
	Phenol	<0.10	<1.0		-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0		200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0		20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0		1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0		10 [2]	0.05ug/L [2]
C6MB	Total Phenols	<20	<5	Dry	20 [3]	-
	Phenol	<0.10	<1.0		-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0		200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0		20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0		1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0		10 [2]	0.05ug/L [2]

Lot / Site	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water criteria (ug/L)*	*Fresh Water [5] Criteria (ug/L)*
C7MB		Dry	Dry	Dry		
C8MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
C9MB	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
CD1	Total Phenols	40	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
CS1	Total Phenols	2700	<5	Dry	20 [3]	-
	Phenol	0.30	<1.0		-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0		200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0		20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0		1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0		10 [2]	0.05ug/L [2]
CS2		Dry	Dry	Dry		

Lot / Site	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water criteria (ug/L)*	*Fresh Water [5] Criteria (ug/L)*
Domestic	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
Rain water tank 1	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
Rain water tank 2	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
103						
Domestic	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]
Rainwater	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]

Lot / Site	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water criteria (ug/L)*	*Fresh Water [5] Criteria (ug/L)*
82						
Domestic	Total Phenols	-	<5	-	20 [3]	-
	Phenol		<1.0	<1.0		50 [4]
	2, 4-Dichlorophenol		<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol		<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol		<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol		<1.0	<2.0	10 [2]	0.05ug/L [2]
Creek						
	Total Phenols	<20	<5	-	20 [3]	-
	Phenol	<0.10	<1.0	<1.0	-	50 [4]
	2, 4-Dichlorophenol	<0.10	<1.0	<1.0	200 [1]	0.20 [2]
	2, 4, 6-Trichlorophneol	<0.20	<1.0	<2.0	20 [1]	-
	2, 4, 5-Trichlorophenol	<0.20	<1.0	<2.0	1.0 [2]	-
	Pentachlorophenol	<0.20	<1.0	<2.0	10 [2]	0.05ug/L [2]

1. Australian Drinking Water Guidelines, 1996, NHMRC/ARMCANZ.
2. Australian Water Quality Guidelines For Fresh and Marine Waters, ANZECC.
3. Limit set by the Health Department.
4. Contaminated Site Assessment Criteria, draft, DEP 2000.

4. ASSESSMENT OF REMEDIATION OPTIONS

4.1 *Hierarchy for Assessment*

Options for the remediation of the contaminated groundwater and soil on the Morangup properties have been assessed by the Waste Management Division of the DEP, and detailed in section 4.2. The proposed remediation strategy is presented to the EPA as part of this EPS and will be assessed through the Environmental Impact Assessment process.

4.2 Remediation Options

The Waste Management Division has identified numerous remedial options for the contaminated soil and groundwater at the Morangup properties. Table 3 investigates the suitability of these options for the affected land. The preferred remediation strategy is outlined in section 4.3.

Table 3 ASSESSMENT OF SOIL AND GROUNDWATER REMEDIAL OPTIONS

Remediation Option		*Description*	*Suitability for the Morangup sites*
Soil	Natural attenuation	Allow natural processes to reduce contamination concentrations to an acceptable level over time.	The soil contamination has been present on the properties for over 25 years and much natural attenuation has already taken place. However, the problematic hydrophobic constituents of the wood tar remain. As such natural attenuation would be a very a long-term option and if employed would prevent the use of the land for its beneficial purposes for many years. Additionally as the contaminated soil would remain it may continue to contaminate the groundwater.
	Capping	Clean fill placed over the contaminated area.	This option would allow most of the beneficial uses of the land to be reinstated, however, restrictions would need to be placed on activities where soil below the capped area was disturbed i.e. excavation of soil for building foundations and swimming pools or growth of deep rooted plants.
	Composting and land farming	Mixing of contamination with bulking agents and organic materials and the land 'farmed" to encourage microbial activity.	This method is relatively long term and would cause major disturbance to the residents for several years. The beneficial use of the land would not be restored for this period of time and further groundwater contamination could occur before the contamination was reduced.
	Excavation and disposal	Removal of contaminated soil and caprock and disposal to an appropriate landfill facility	This would restore the beneficial use of the land quickly and would prevent further groundwater contamination. However, the removal of contaminated caprock would involve extensive blasting and raise associated safety, noise, vibration and traffic issues.

	Remediation Option	*Description*	*Suitability for the Morangup sites*
	Excavation, capping and disposal	The removal of contaminated soil to landfill and the capping of contaminated caprock.	This method would restore beneficial use of the land quickly with minimal disturbance to residents and would prevent further groundwater contamination. Capping the caprock would significantly reduce the potential for leaching of contaminants from the caprock to the groundwater.
Groundwater.	Natural attenuation	Allow natural processes such as dilution and biodegradation to reduce groundwater contamination over time	This would involve long term monitoring of the contaminated plumes and possible restrictions on groundwater use. However, it is least intrusive to the environment and residents and is considered appropriate given the low contamination levels and the removal of the contamination source.
	Aeration	To increase the contact between the contamination and the air, by mechanical devices, to promote biodegradation	This option will require the installation of infrastructure and several years of monitoring and possible restrictions on groundwater use. Additionally the nature of the aquifer would make isolation of the source very difficult. This process is more expensive than natural attenuation and is not warranted given the contamination levels.
	Enhanced biodegradation	Bioremediation by microbes enhanced by the increased concentration of electron receptors and nutrients.	This method is not proven on phenols and its success is dependent upon groundwater flows and circulation in the area. It would involve significant investigation and trialing prior to initiation of this technique.

4.3 Preferred Remediation Strategy

The Waste Management Division believes the most appropriate remediation option is to excavate and dispose of contaminated soil, seal contaminated caprock and monitor groundwater contamination as it naturally attenuates.

This option would involve:

- Excavation of the top 250mm of the soil from visibly contaminated areas;
- Excavation of the soil deeper than 250mm containing concentrations of contaminants exceeding 9mg/kg of total phenols and disposal at Colebatch Road Class II landfill facility or other licensed Class I or II landfill facility;
- Delineation and sealing of contaminated caprock;
- Backfilling of excavated areas with clean fill;
- Monitoring of groundwater contamination and restrictions on its use, as necessary.

5. COMMUNITY CONSULTATION

5.1 Target groups

The following groups have been identified as having an interest or potential interest in the remediation of the contamination on Morangup Road:

- Landowners affected by contamination
- Neighbours and nearby residents potentially affected by remediation operations
- Residents along transport route to the landfill
- Morangup community
- Toodyay community
- Local action groups (Avon Clean & Green, Avon Valley Environmental Society, Toodyay Naturalists)
- Local media (Morangup News)
- Other media (papers, TV and radio)
- Indigenous community
- State and local government agencies (Contaminated Sites Branch, Waters and Rivers Commission, Health Department of Western Australia and Shire of Toodyay)
- Shire of Toodyay councilors

5.2 Processes for Communication

The DEP has used, and will continue to use, the following processes to communicate with the target groups:

- Personal contacts with property owners and neighbors
- Group meetings with residents
- Letter drops
- Open days
- Media releases
- Advertisements in local newspapers

5.3 Public Consultation to Date

The Pollution Prevention Division (PPD) of the DEP began communication with the owners of the affected properties in 1996. In 1997 a preliminary investigation into the extent and nature of contamination was initiated by PPD (*CMPS&F, Phase 2 Report, Morangup Road Toodyay, September 1997*). Results of this work and subsequent sampling were communicated to the landowners.

During 2000 when more detailed investigations were undertaken by the Waste Management Division of the DEP, contact with the affected landowners became more frequent. In October, prior to the soil characterisation program, a letter drop to nearby residents was carried out informing them of these activities and the likely program for remediation of the sites. Regular meetings were held with the affected landowners to

explain the outcome of investigations and copies of the reports were distributed. A record community consultation is provided in Table 4.

Table 4 RECORD OF COMMUNITY CONSULTATION

Date	*Method of Communication*	*Recipient*	*Description*
6/09/00	Letter	Affected residents	Progress update and copies of investigation reports
14/09/00	Home Visit	Owners of Lot 12	Information regarding potential health risks and an update on progress of investigations.
5/10/00	Letter	Affected residents	Progress update and copies of latest reports
12/10/00	Meeting	Owners of Lot 82	Information on progress of remediation
18/10/00	Letter Drop	All nearby residents	Information on the nature of the contamination and the proposed remediation progress
22/02/01	Home Visit	Owners of Site A and B	Discussion of possible dust suppression measures
26/02/01	Meeting	Affected residents	Health Department's principal toxicologist discussed the potential health issues associated with the contamination
2/03/01	Home Visit	Owners of Site C	Offered dust suppression measures
9/03/01	Home Visit	Owners of Lot 82	Provided a tour and explanation of dust suppression measures on neighbouring sites
23/03/01	Home Visit	Owners of Lot 12	Update on progress of remediation and delivered copies of the investigation reports
23/03/01	Home Visits	Owners of Lot 4	Update on progress of remediation and delivered copies of the investigation reports
18/05/01	Meeting	Affected residents and interested community groups	Update on progress of the remediation and proposed timeframes

Note: there have also been numerous phone conversations with the affected residents, Shire of Toodyay and local community group Avon Clean and Green. These conversations have involved answering community questions and updating people on the progress of the project.

5.4 Major Community Issues

Public consultation to date has determined three main concerns among the residents. These concerns and how they will be addressed are detailed in Table 5.

Table 5 MAJOR COMMUNITY CONCERNS

Community Concern	*Management Measures*	*Relevant Section in the EPS*
Inability of the land to support plants and crops	The hydrophobic top layer of the contaminated soil will be removed on all properties regardless of contamination levels and replaced with clean fill. This will allow the growth of plants. A phytotoxocity study has determined that the remaining soil, all of which will have a total phenol concentration of less than 9mg/kg, will not affect plant growth of quality in any way.	Section 6.2
Dust generation and its possible health effects	The Health Department has undertaken a risk assessment on the dust and determined that it poses no health risk from the contaminants. However, the dust itself may exacerbate pre existing respiratory and cardiovascular conditions. As such the Waste Management Division has employed dust suppression measures on two of the contaminated properties to reduce dust generation until the remediation is completed. Rainwater tanks on the properties have also been monitored on a six monthly basis to ensure dust is not contaminating the tanks A trial excavation and soil wetting agent experiment has been undertaken. The findings will be used in the development of dust management measures, which will be detailed in the EMP. These measures will be approved by the EPA and will include monitoring and the use of action levels.	Appendix 7 Section 7.2 Section 3.4 Appendix 8
Reduction in property values because of the contamination	The removal of contaminated soil (above 9mg/kg of total phenols), monitoring of groundwater and sealing of caprock will allow land to be used for all beneficial purposes. However, a notice on the title of the properties with caprock may be required to prevent people disturbing the caprock seal. This has the potential to lower the properties value. The removal of the caprock has been determined to be unwarranted and expensive.	Section 4.2 Section 4.2 Table 3

5.5 Government Agencies

In August 2000 the Waste Management Division established a Project Team to assist with the planning process for the remediation of the Morangup contaminated sites.

This team consisted of officers from numerous agencies who had expertise in areas relevant to the project.

The agencies involved and their roles are outlined in the Table 6.

Table 6 PROJECT TEAM MEMBERSHIP

Agency	*Role within the Project Team*
Waste Management Division, DEP	Project Managers for the remediation operation.
Contaminated Sites Branch, DEP	Advice regarding the contaminated sites legislation, investigation levels and methodology of investigations.
Air Quality Branch, DEP	Advice and technical expertise regarding dust monitoring, air quality and the interpretation of air monitoring data.
Health Department	Advice on potential health risks associated with the contamination, and assistance with the establishment of action and alert levels.
Waters and Rivers Commission	Advice and technical assistance regarding the management, monitoring and characterisation of the groundwater contamination.
Executive Officer to EPA	Advice regarding the requirements of the environmental impact assessment process.
CAMS	Assistance in the development of tender documents for characterisation and remediation.
Shire of Toodyay	Specialist advice regarding the Morangup area and the potential problems and issues within that region.

6. DESCRIPTION OF THE REMEDIATION

6.1 Objectives

The DEP has resolved to remediate the contaminated sites in a manner which fulfils the following objectives:

- Landowners are able to utilise their properties for the land's intended beneficial uses, and
- Any wood tar remaining on the sites poses no threat to human health or the environment.

6.2 Soil and Caprock

6.2.1 Timetable

The planned duration of the remediation works is 13 weeks. The proposed timetable and activities are set out in Table 7, and will be confirmed in the EMP.

TABLE 7 REMEDIATION TIMETABLE

ACTIVITY	ESTIMATED TIME PERIOD
Mobilise to site	5 days
Remove fences, infrastructure and vegetation	8 days
Apply soil wetting agent and wet and rip the area	6 days
Excavate top 250mm of contaminated soil	8 days
Excavate and dispose of any remaining contamination above 9mg/kg	10 days
Delineate and seal contaminated caprock	10 days
Backfill excavated areas	5 days
Reinstate infrastructure and fences	5 days
Rehabilitate sites	7 days
Demobilise from site	3 days

6.2.2 Removal of fences and infrastructure

Prior to the commencement of any excavation works on the sites, all infrastructure and fences within the contaminated area will be removed. This includes a large shed on Site C and possibly internal fences on sites A and C.

Any bores within the excavation area shall be fully protected and left undamaged following excavation and backfilling works. If any property is damaged in any way it shall be fully reinstated on completion of excavation and backfilling works.

6.2.3 Removal of contaminated soil

The removal of contaminated soil from the affected properties is planned to be conducted in the following manner:

1. Soil wetting agent applied to contaminated soil four and two weeks prior to excavation and the soil ripped and thoroughly wet;
2. Soil wetting agent and water applied to contaminated areas approximately two days prior to excavation and to the working face, throughout excavation and loading activities;
3. Top 250mm of contaminated soil excavated using a front-end loader and placed into trucks for disposal off site to Colebatch Road Class II landfill facility, or other approved Class I or II landfill facility.
4. All soil with a total phenol concentration above 9mg/kg (as determined during previous sampling programs) excavated for disposal to the Colebatch Road Class II Landfill facility or other approved Class I or II landfill facility.
5. Excavated contaminated soil loaded into sealed tray trucks for disposal;
6. Uncontaminated areas over contaminated caprock excavated using a backhoe and stockpiled for use as backfill;
7. Excavated areas validated and contaminated caprock sealed;
8. Uncontaminated material and imported clean fill used to backfill excavated areas to within 250mm of the finished surface;
9. Imported topsoil used to backfill upper 250mm.

All excavations shall be undertaken to prevent cross contamination and minimize the potential risks associated with the removal of contaminated soil.

6.2.4 Contaminated caprock

The contaminated caprock on the properties will not be removed, but will be sealed to prevent leaching of contaminants into the groundwater. The full extent of the contamination is not known at this time, however, the following steps will be undertaken to delineate the contamination.

1) Caprock suspected of being contaminated will be drilled at 10m square grids and closed to 5m to assess the contamination boundaries.
2) Drill samples will be taken at depths of 250mm and 500mm and anaylsed for phenols. The phenol concentration will then determined by averaging the concentrations in the two samples.
3) The contamination boundaries will be taken as the line through the first non contaminated (less than 9mg/kg of total phenols) drill sample outside the contaminated area.

Once the contamination boundaries have been determined the caprock will be sealed using one of the following techniques, which will be determined by the DEP and the contractor, in consultation with the EPA:

- 75mm of betonite/cement mortar;
- 150mm of compacted granular material, followed by a Geo-synthetic clay liner and a 0.5mm thick welded polypropylene geomembrane; or
- 450mm clay blanket applied in two layers and compacted to 95% density. This will not be utilised where the caprock is less than 1500mm from the surface.

All excavated areas will then be backfilled.

6.2.5 Validation Procedures

Validation of the adequacy of the remedial works will be undertaken at three stages of the process:

1. All contaminated material to be excavated is considered suitable for disposal at a Class I or II landfill facility, in accordance with the *Guidelines for the Acceptance of Solid wastes to Landfill,* DEP 2001. A program of in situ sampling and testing has been undertaken on the material in order to confirm this expectation and to allow the material to be excavated directly into trucks for transport and disposal.
2. Sampling and analysis of the vertical profile of the excavated area at 15m intervals across the horizontal profile. At each 15m interval, samples will be taken at depth intervals of 1m. Where the excavation is less than 1m deep, samples will be taken at the surface and the base of the excavation wall.
3. Sampling and analysis of all imported clean fill to ensure it is free from contamination and disease, especially phytophthora (dieback). All fill material shall comply with residential criteria as specified in *Contaminated Site assessment criteria, DEP 2000.*

6.2.6 Transport

All vehicles transporting contaminated materials from the site shall conform to the following requirements:

- No contaminated material protrudes above the top of the tray;
- All trays are sealed and covered in a firmly secured tarpaulin which extends well over the edge of the tray;
- If any contaminated material is lost from the vehicle, transport will cease immediately and the material removed from the road.

All vehicles departing the sites will have their wheels and suspension washed down to prevent material being dropped outside the site. Any adhered material on other surfaces of the vehicles shall also be washed before departing the site.

Warning devices and traffic control will be erected at the sites in accordance with *AS1742.3 Manual for Uniform Traffic Control Devices 1985.* These devices will be sufficient to ensure the efficient and safe movement of external and site related traffic.

6.2.7 Disposal

As indicated in section 6.2.5 all waste has been sampled in accordance with the requirements of the *Guideline for the Acceptance of Solid Waste to Landfill, DEP 2001* to confirm its suitability for disposal to a Class I or II landfill (appendix 6).

Arrangements are being made with the Colebatch Road Waste Management Facility, in Northam, to accept the waste. This facility is a 45km drive from the affected properties through sparsely populated areas.

6.3 *Rehabilitation*

Following remedial works the sites will be rehabilitated in accordance with the future requirements of land. This will be negotiated directly with the landowners.

If a property is to be revegetated to a natural state, all plant species planted will be indigenous to the Morangup region and seeds will be sourced from nearby areas. This will ensure all plants are grown from seeds of local provenance. The Avon Valley National Park may provide any required seed stock.

6.4 Groundwater Monitoring and Management

6.4.1 Objectives

The DEP has resolved to manage the groundwater contamination in accordance with the following objectives:

1) Prevent the further contamination of groundwater; and
2) Ensure any potential health or environmental risk from the remaining contaminated groundwater is effectively managed.

6.4.2 Strategy

The contaminated groundwater is not posing an ecological or human health risk. As such it has been decided that natural attenuation be adopted as the remediation strategy for the area. This strategy will include long term monitoring of the plumes and the provision of restrictions on abstraction of water if necessary.

6.4.3 Monitoring Program

In November 2000 the Waste Management Division began six monthly sampling of groundwater under and near the contaminated sites on Morangup Road. The samples, collected by the Water and Rivers Commission, were analysed for phenols, BTEX, TPH and PAH, and compared with available drinking water criteria (Table 8).

BTEX consist of benzene, toluene, ethylbenzene and xylene, each of which has a drinking water criteria specified in the *Contaminated Site Assessment Criteria (draft), DEP 2000.* No samples analysed have exceeded drinking water criteria.

No drinking water limit has been established for PAH, however a criteria has been specified for benzo(a)pyrene, the most toxic PAH. As such benzo(a)pyrene can be used to determine if PAH levels are acceptable in drinking water. Unfortunately the criteria for benzo(a)pyrene is below the detection limit used for the samples. All future sampling will use a lower limit.

TPH have no drinking water criteria as they are generally used as an indicator of the type of contamination present. Total TPH are presented in Table 8, however sample results show that the type of TPH found are C9-C29 chains. These are consistent with phenol contamination. Phenol sample results are presented in Table 2.

Sampling of the groundwater will continue following the remediation operation and a bore will continue to be sampled until four consecutive 6 monthly samples show no contamination. New monitoring bores will be established as the contamination plume migrates.

Table 8 **COMPARISON OF GROUNDWATER AND DRINKING WATER CRITERIA**

Lot/Site	*Monitoring Bore*	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water Criteria (ug/L)*
Site A	Domestic	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250	-	<250	-
	AS2	Benzene	<1.0	-	dry	1.0
		Toluene	<0.25	-		800
		Ethylbenzene	<0.25	-		300
		Xylene	<2.0	-		600
		Benzo(a)pyrene	<0.10	<0.5		0.01
		Total TPH	<250	-		-
	AD2	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	2800		2000	-
	A1MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	1300		1700	-

Lot/Site	*Monitoring Bore*	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water Criteria (ug/L)*
	A2MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		1000	-
Site B	B1MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	B2MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
Site C	C1MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-

Lot/Site	*Monitoring Bore*	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water Criteria (ug/L)*
	C2MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	C3MB	Benzene	<1.0	-	dry	1.0
		Toluene	<0.25	-		800
		Ethylbenzene	<0.25	-		300
		Xylene	<2.0	-		600
		Benzo(a)pyrene	<0.10	<0.5		0.01
		Total TPH	<250			-
	C4MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	940		990	-
	C5MB	Benzene	<1.0	-	dry	1.0
		Toluene	<0.25	-		800
		Ethylbenzene	<0.25	-		300
		Xylene	<2.0	-		600
		Benzo(a)pyrene	<0.10	<0.5		0.01
		Total TPH	<250			-

Lot/Site	*Monitoring Bore*	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water Criteria (ug/L)*
	C6MB	Benzene	<1.0	-	dry	1.0
		Toluene	<0.25	-		800
		Ethylbenzene	<0.25	-		300
		Xylene	<2.0	-		600
		Benzo(a)pyrene	<0.10	<0.5		0.01
		Total TPH	<250			-
	C7MB		dry	dry	dry	
	C8MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	C9MB	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	CD1	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	3000		2400	-

Lot/Site	*Monitoring Bore*	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water Criteria (ug/L)*
	CS1	Benzene	<1.0	-	dry	1.0
		Toluene	<0.25	-		800
		Ethylbenzene	<0.25	-		300
		Xylene	<2.0	-		600
		Benzo(a)pyrene	<0.10	<0.5		0.01
		Total TPH	2300			-
	CS2		dry	dry	dry	
	Domestic	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	Rain tank 1	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	Rain tank 2	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-

Lot/Site	*Monitoring Bore*	*Component*	*Nov 2000 Sample Result (ug/L)*	*Dec 2000 Sample Result (ug/L)*	*May 2001 Sample Result (ug/L)*	*Drinking Water Criteria (ug/L)*
103	Domestic	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
	Rain tank	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-
82	Domestic	Benzene	-	-	<1.0	1.0
		Toluene		-	<1.0	800
		Ethylbenzene		-	<1.0	300
		Xylene		-	<2.0	600
		Benzo(a)pyrene		<0.5	<1.0	0.01
		Total TPH			<250	-
Creek	N/a	Benzene	<1.0	-	<1.0	1.0
		Toluene	<0.25	-	<1.0	800
		Ethylbenzene	<0.25	-	<1.0	300
		Xylene	<2.0	-	<2.0	600
		Benzo(a)pyrene	<0.10	<0.5	<1.0	0.01
		Total TPH	<250		<250	-

* Phenol contamination and drinking water criteria are presented in Table 2

6.4.4 Management and Contingency Plans

Should monitoring show contamination levels above the accepted criteria, an appropriate action, approved by the EPA on advice from the Water and Rivers Commission, will be implemented. This may involve:

- A caveat on abstraction; or
- Capping of the affected bore and installation of a new bore on an unaffected area of the property

These will be performed through the existing licensing provisions within the Waters and Rivers Commission.

7. ENVIRONMENTAL FACTORS AND MANAGEMENT

During the remediation of the affected properties the potential for social and environmental impacts on the local community could arise. The management of these impacts will be specifically detailed within the EMP, which will be prepared by the Contractor prior to the commencement of work on site. The following section provides general information on the management of the main impacts.

7.1 Health and Safety

The remediation of the affected properties will involve the handling of contaminated materials using heavy machinery. These activities involve the management of numerous potential health and safety risks.

Although the wood tar contamination is not expected to induce any adverse health effects a Health and Safety Plan will be developed prior to the commencement of site works to outline the management procedures and measures for the management of potential exposure risks and risks associated with earthworks procedures. The Health and Safety plan will detail the use of safety measures such as:

1) Education and induction training prior to commencement of remedial works to ensure personnel are aware of the nature of the materials, exposure risks and routes, and precautions in place;
2) Appropriate personal protective equipment to be worn by all personnel on site;
3) Operators of plant equipment to keep cabin doors and windows closed whilst excavating;
4) Appropriate emergency equipment to be available on site;
5) Emergency response plan will be drafted;
6) Contaminated areas to be clearly marked;
7) Excavation areas to be appropriately fenced and access to the site limited, for safety reasons.

The Health and Safety Plan will comply with all legislative requirements and shall be forwarded to the Health Department and Worksafe for comment prior to finalisation. No work will commence on site until the Health and Safety Plan has been finalised.

7.2 Dust

Due to the hydrophobic nature of the wood tar contamination there is the potential for significant dust generation during the remedial works. The Department of Health has performed a Health Risk Assessment on the dust (Appendix 7) and concluded that while the contamination in the dust poses no threat to human health, dust of any type may lead to the exacerbation of preexisting cardiovascular and respiratory conditions.

In order to develop effective dust management procedures a trial excavation was undertaken in late 2000. A copy of the report on the trial is included as Appendix 8.

As a result of the trial excavation findings the Contractor will be required to implement dust management techniques, which will be detailed in the EMP and approved prior to commencement of excavation. These techniques are expected to include the following:

1. Soil wetting agent applied to the contaminated soil two and four weeks prior to the commencement of site works and the soil ripped and wet;
2. Soil wetting agent applied to contaminated soil two days prior to site works and the soil saturated to a depth of 200-300mm;
3. Soil wetting agent and water continually applied to the working face throughout site works.

Air monitoring equipment will be installed at the following locations prior to the commencement of site works:

- Two portable aerosol monitors, 2m above ground and 50m downwind of the area in which remediation is being undertaken;
- Portable aerosol monitor on stand-by;
- High volume sampler located at the nearest occupied house;
- Wind speed and direction unit located 2m above ground level.

A two day trial of the monitoring equipment will be undertaken prior to the commencement of the remediation. This trial will test the monitoring equipment and determine the background dust levels for the sites. The results of the trial will be subject to review and approval by the EPA prior to the commencement of the full remediation. The requirements of the trial will be provided in the EMP.

The amount of dust generated throughout the remediation, will be monitored and work ceased immediately if action levels are reached. Work will not recommence until safe emission levels can be achieved. Each portable aerosol monitor will be fitted with a visual alarm to alert personnel should action levels be reached. The action levels will be developed in consultation with the Department of Health and approved by the EPA, as part of the EMP.

All monitoring equipment used during the remediation will be appropriately calibrated and no site activities will be undertaken if any equipment is not functional.

7.3 Surface Water

Remediation of the sites will be managed to prevent or minimize storm water runoff from entering contaminated areas. Any run-off from the contaminated areas will be contained and tested prior to disposal.

7.4 Transport

Transportation of material from the sites will be undertaken in accordance with all relevant traffic legislation and best working practices. The following measures may be

implemented to ensure that the risk of accidental spillage is minimized and any incidents effectively managed:

- Drivers will be briefed on all transport requirements prior to beginning work;
- Trucks will be contactable at all times by two-way radio;
- Trucks will be equipped with basic spill containment equipment;
- Chain of command information including contact names and telephone numbers for clean up crews and emergency authorities will be in all trucks
- Trucks will contain information on the hazard potential and characteristics of the contamination;
- An emergency response plan will be drafted dealing with accidental spillage;
- Waste will be transported in covered and sealed trucks;
- Trucks will be loaded within the volume and weight capacity for that vehicle;
- Waste material will be assigned a consignment number prior to leaving the site to ensure all material reaches the appropriate destination;
- Vehicles will be washed down before leaving the sites; and
- Trucks will be inspected prior to departure to ensure their cover and tailgates are secured correctly.

It is likely that the waste will be taken to the Colebatch Road Waste Management Facility. The transport route from the sites to the Colebatch Road facility is outlined in Figure 9. This route is only 45km long and does not pass through any towns or heavily populated areas.

Confirmation of the disposal location of the waste will be provided in the EMP and the appropriate transport route confirmed. Trucks will be required to use the designated transport route.

7.5 Noise

All contractors on site will be obliged to meet the requirements of the *Environmental Protection (Noise) Regulations 1997*. In order to achieve this and minimise disruption the following actions will be employed:

1. Machinery will generally operate only during day light hours between 7 and 18.00 Monday to Saturday;
2. All equipment will be in good working order with effective silencers;
3. Occupational noise exposure will be in compliance with WorkSafe WA requirements thus limiting potential for off site impacts; and
4. The remediation contractor will be required to undertake noise monitoring to the requirements of the EMP to provide evidence of compliance with noise regulations. Modifications to equipment will be required if noise levels are found to exceed the regulatory standard.

7.6 Disposal

In-situ sampling programs at the sites indicate that the contaminated material is suitable for disposal at a Class I or II landfill, in accordance with the *Guidelines for Acceptance of Solid Waste to Landfill*, 2001.

Arrangements are being made with the Town of Northam for the soil to be taken to the Colebatch Road Waste Management Facility landfill 45km from the sites. Officers from the Waste Management Division visited this facility in April and found it to be well managed. The disposal location of the waste will be confirmed in the EMP.

The waste will be stored at the landfill facility for use as daily cover over the next year. The waste stockpile will be covered and the working face will be kept wet to prevent dust generation and soil leaching. Provided that these measures are used the waste poses no environmental or health risk within the landfill facility.

7.7 Vegetation and Flora

The Evaluation Division of the DEP have determined that the removal of vegetation on the affected properties is not environmentally significant and is not notifiable under the *Soil and Land Conservation Act, 1945.* This is because the ecological health of the vegetation on the properties has been inhibited by the contamination and the areas to be cleared are small.

Following remedial works, the sites will be rehabilitated in accordance with the future requirements of land. This will be negotiated directly with the landowners and detailed in a rehabilitation plan.

If a property is to be revegetated to a natural state, all plant species planted will be indigenous to the Morangup region and seeds will only be sourced from the surrounding area. This will ensure all plants are grown from seeds of local provenance. The nearby Avon Valley National Park may provide any required seed stock.

7.8 Social

It is unlikely the remedial works will significantly affect the local community or residents. Risks from the works will be minimized and the residents on the properties will not need to be relocated. Residents in the immediate vicinity will experience some inconvenience but this should be limited as dust, noise and road disturbance will be minimized. Additionally the time span involved in the clean up is relatively short.

ENVIRONMENTAL MANAGEMENT COMMITMENTS FOR REMEDIATION OF CONTAMINATED SITES AT MORANGUP, SHIRE OF TOODYAY (Assessment No 1391)

No.	Topic	Actions	Objectives	Timing	Requirements/Advice
1	**Environmental Management Plan**	Develop an environmental management plan for the remediation of contaminated soil and caprock at Morangup, addressing: o Removal and restoration of fences and infrastructure o Occupational health and safety o Dust monitoring and management (including a two day dust trial to test monitoring equipment and establish background levels, and development of dust action levels, established on advice from the Department of Health) o Noise and vibration o Surface water management o Contaminated caprock delineation and capping o Excavation of contaminated soil o Transport of contaminated soil o Management of contaminated soil at landfill site o Validation prior to backfilling o Rehabilitation o Public communication and complaints resolution	To ensure that the contaminated sites at Morangup are remediated to a level and in a manner that is protective of human health and the environment.	Prior to commencement of full scale remedial works.	**Requirements of:** EPA **On advice from:** DOH, WRC, Worksafe
2	**Environmental Management Plan**	Make the Environmental Management Plan publicly available.	To ensure that the contaminated sites at Morangup are remediated to a level and in a manner that is protective of human health and the environment.	Prior to commencement of full scale remedial works.	**Requirements of:** EPA

No.	Topic	Actions	Objectives	Timing	Requirements/Advice
3	**Environmental Management Plan**	Implement the Environmental Management Plan.	To ensure that the contaminated sites at Morangup are remediated to a level and in a manner that is protective of human health and the environment.	Commencement of full scale remedial works.	**Requirements of:** EPA
4	**Public Consultation**	Liaise directly with affected property owners and residents adjacent to the contaminated sites at Morangup and provide regular community consultation and communication process by regular newsletters and information sessions for the public.	To inform the community of the progress of remediation at the Morangup contaminated sites and facilitate communication between the affected landowners and adjacent residents and the proponent on the performance of the remedial works. To address issues as they arise and communicate details regarding progress, timing, impacts and likely completion, between the involved parties.	Prior to, during remedial works and at the conclusion of the validation report.	**Requirements of:** EPA
5	**Groundwater Monitoring and Management Plan**	Develop a long term monitoring and management plan for contaminated groundwater at and down hydraulic gradient of the contaminated sites at Morangup, addressing: o Siting and construction of additional bores; o Monitoring program (analyses and frequency); o Management to restrict access to contaminated groundwater; and o Contingency measures.	To ensure future groundwater quality is managed to protect human health and the environment.	At completion of remedial works.	**Requirements of:** EPA **On advice from:** WRC
6	**Groundwater Monitoring and Management Plan**	Make the Groundwater Monitoring and Management Plan publicly available.	To ensure future groundwater quality is managed to protect human health and the environment.	At completion of remedial works.	**Requirements of:** EPA

No.	Topic	Actions	Objectives	Timing	Requirements/Advice
7	**Groundwater Monitoring and Management Plan**	Implement the Groundwater Monitoring and Management Plan.	To ensure future groundwater quality is managed to protect human health and the environment.	At completion of remedial works.	**Requirements of:** EPA **On advice from:** WRC
8	**Validation Report**	**Action:** Submit a report within two months following completion of site work to the EPA, which provides evidence of conformance to the Environmental Conditions and Commitments for the project.	To document that the clean up of the contaminated sites at Morangup has been performed in accordance with EPA requirements.	Within two months following completion of remedial works.	**Requirements of:** EPA **On advice from:** DOH

Legend:

EPA	Environmental Protection Authority
DOH	Department of Health, Western Australia
WRC	Water and Rivers Commission
Agwest	Agriculture Western Australia

9.0 REFERENCES

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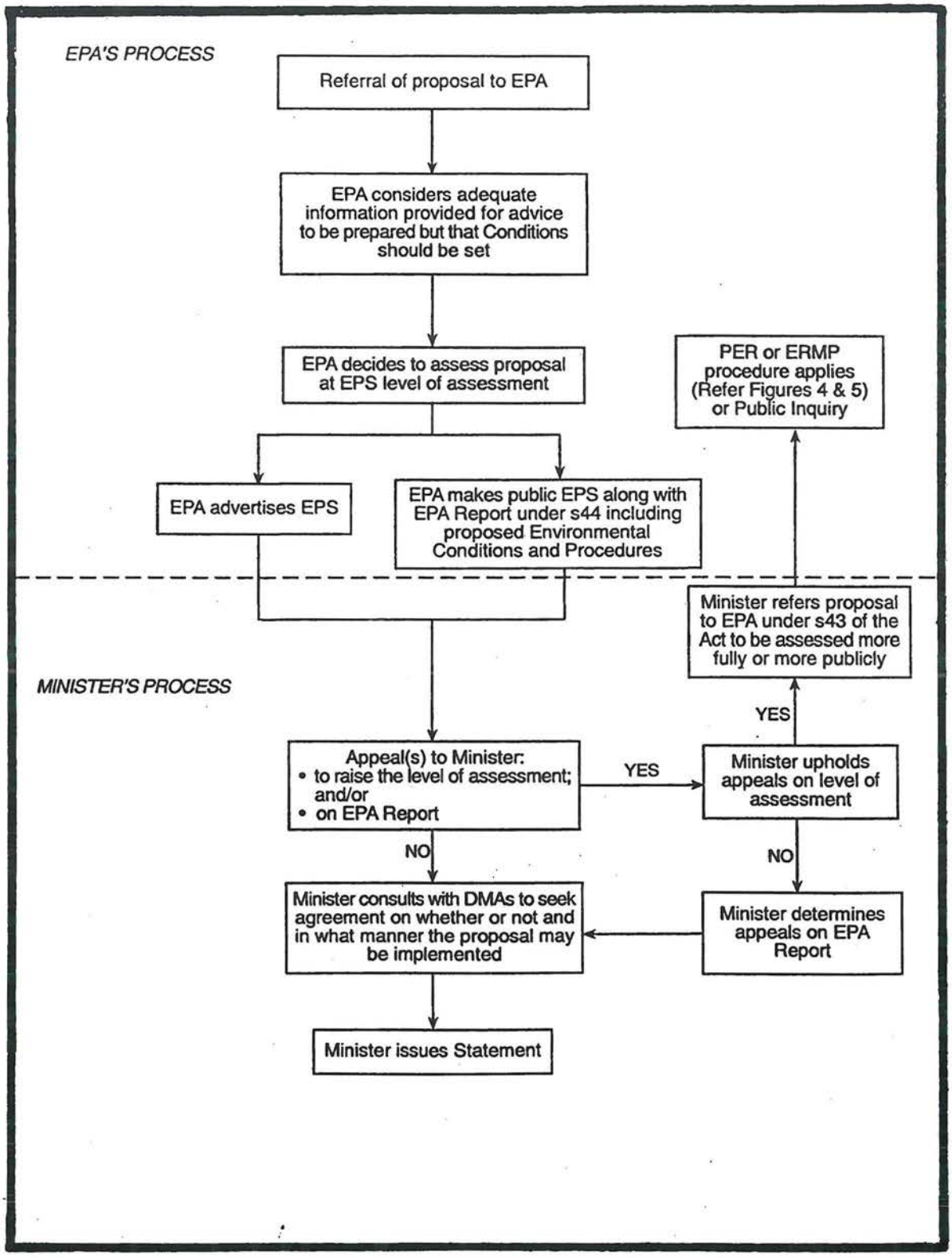
FIGURES

FIGURE 1 - PROCEDURE FOR EPA INITIATED ENVIRONMENTAL PROTECTION STATEMENT (EPS)



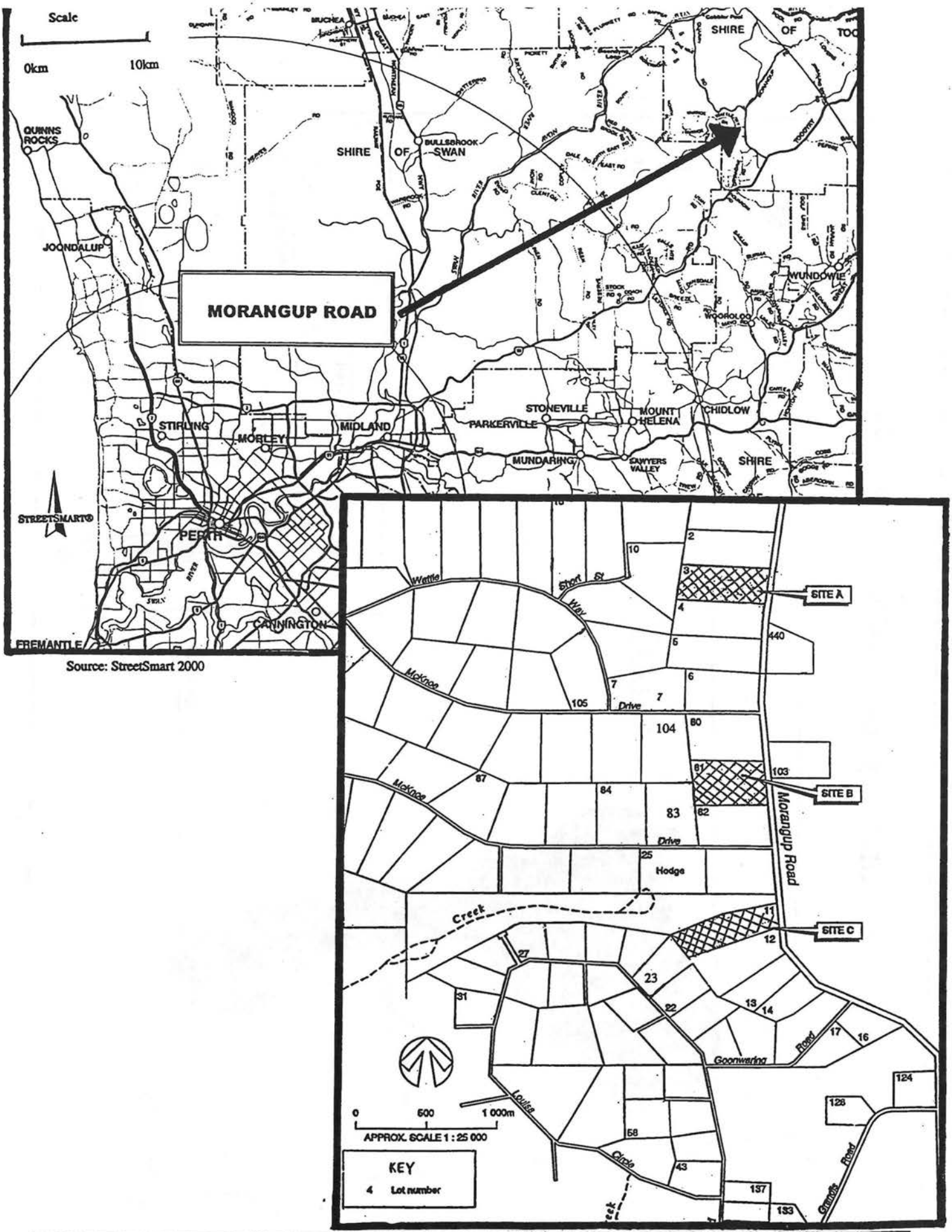


FIGURE 2

LOCATION OF CONTAMINATED SITES ON MORANGUP ROAD

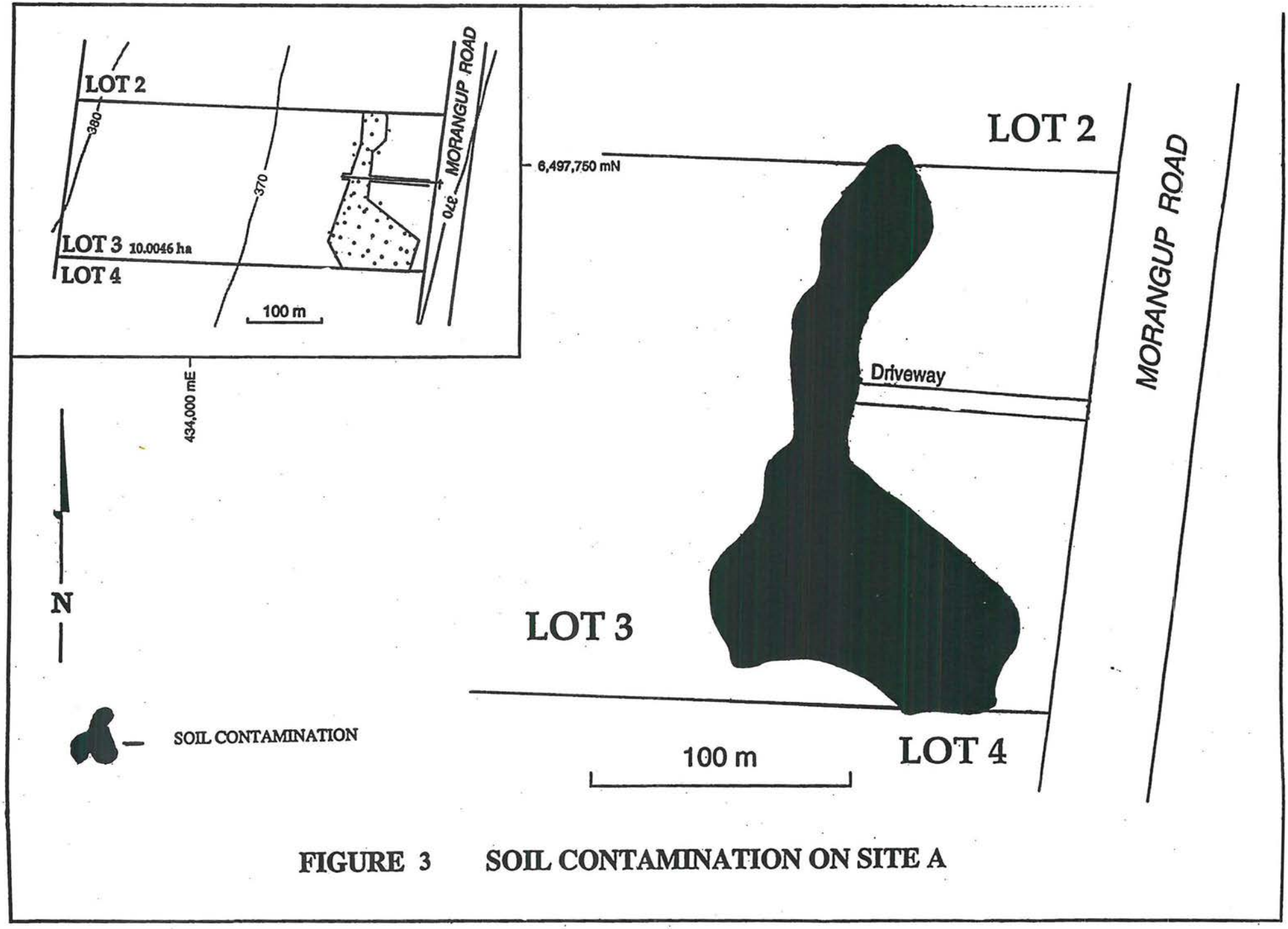


FIGURE 3 SOIL CONTAMINATION ON SITE A

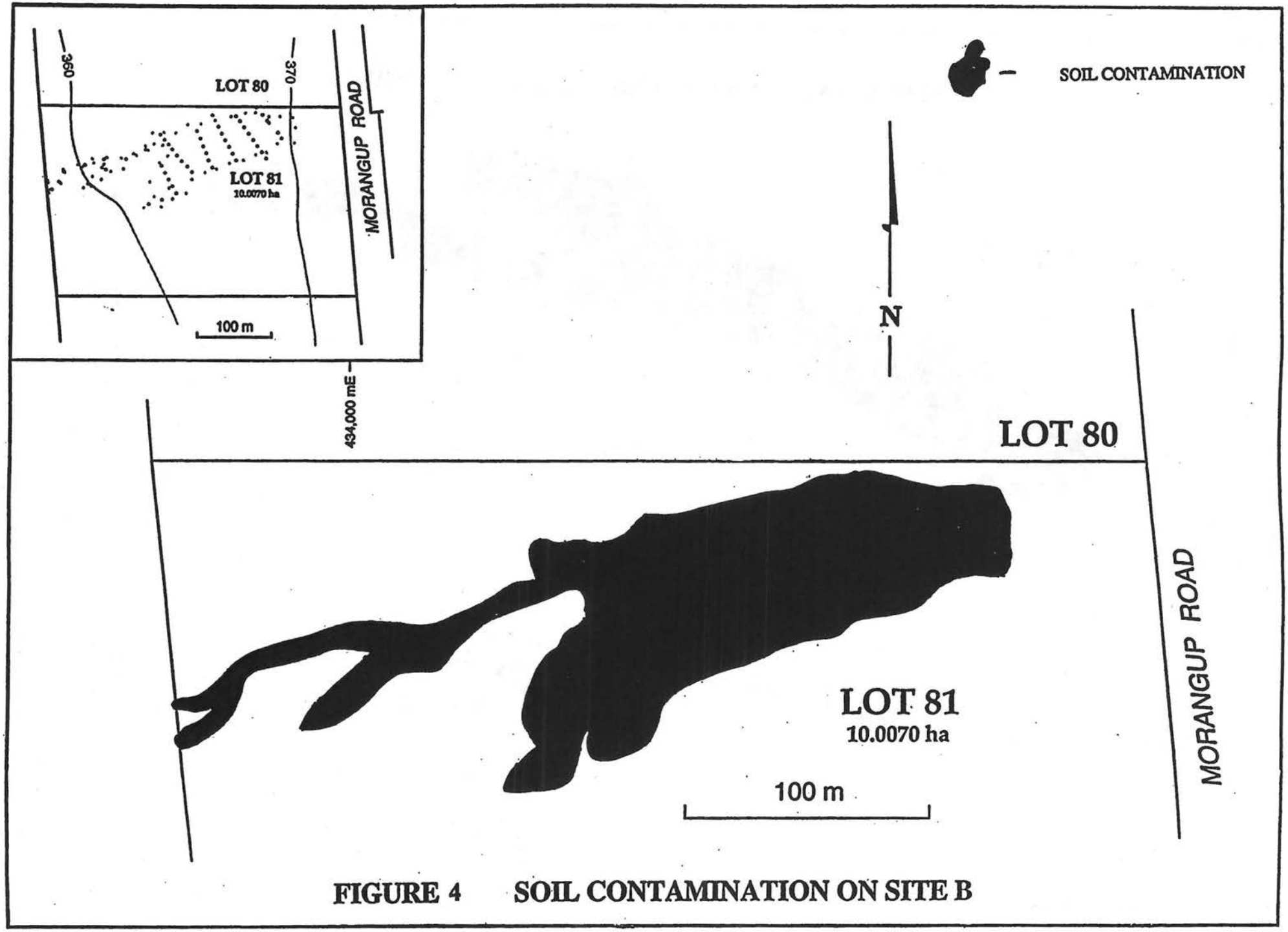


FIGURE 4 SOIL CONTAMINATION ON SITE B

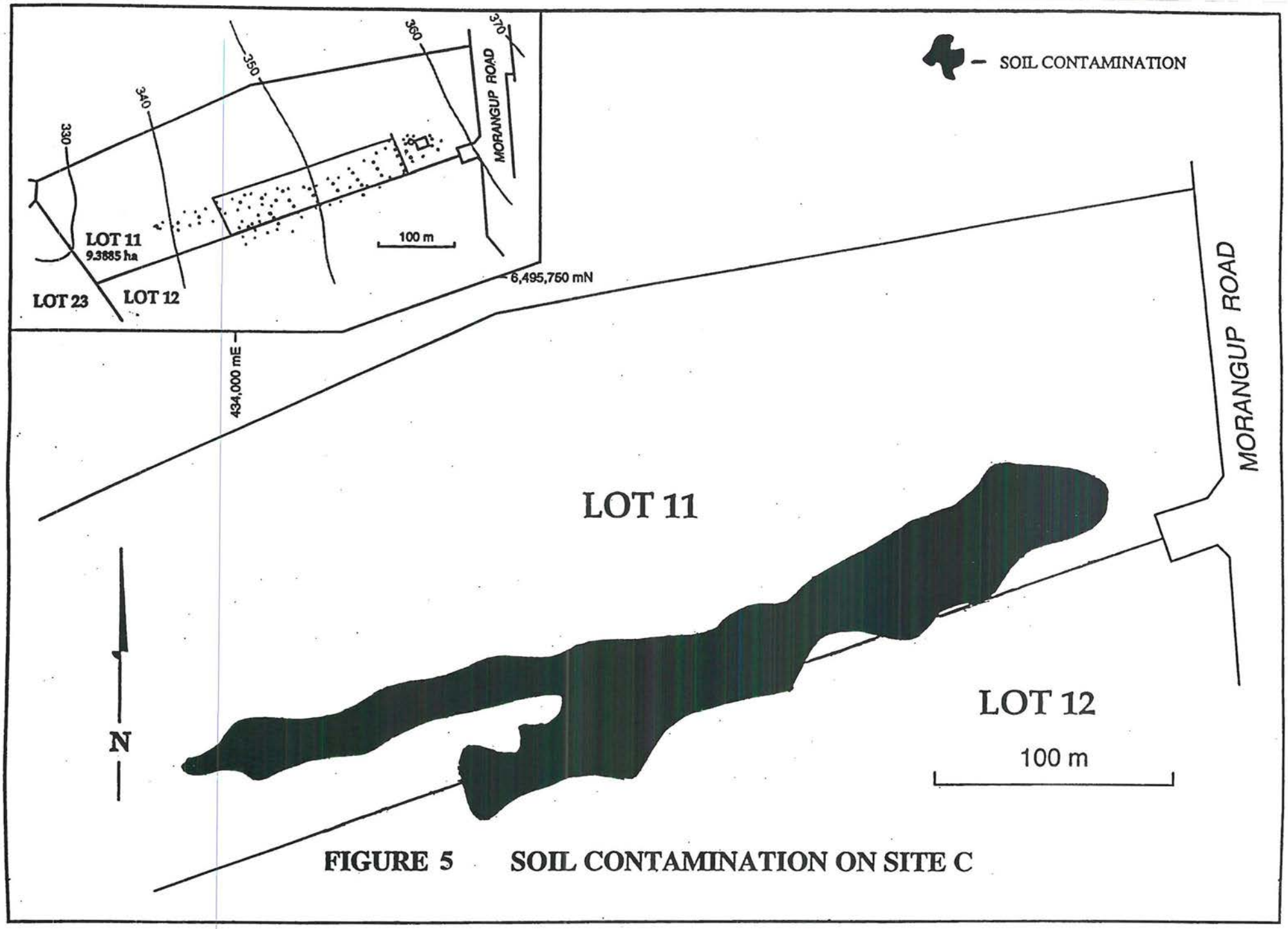


FIGURE 5 SOIL CONTAMINATION ON SITE C

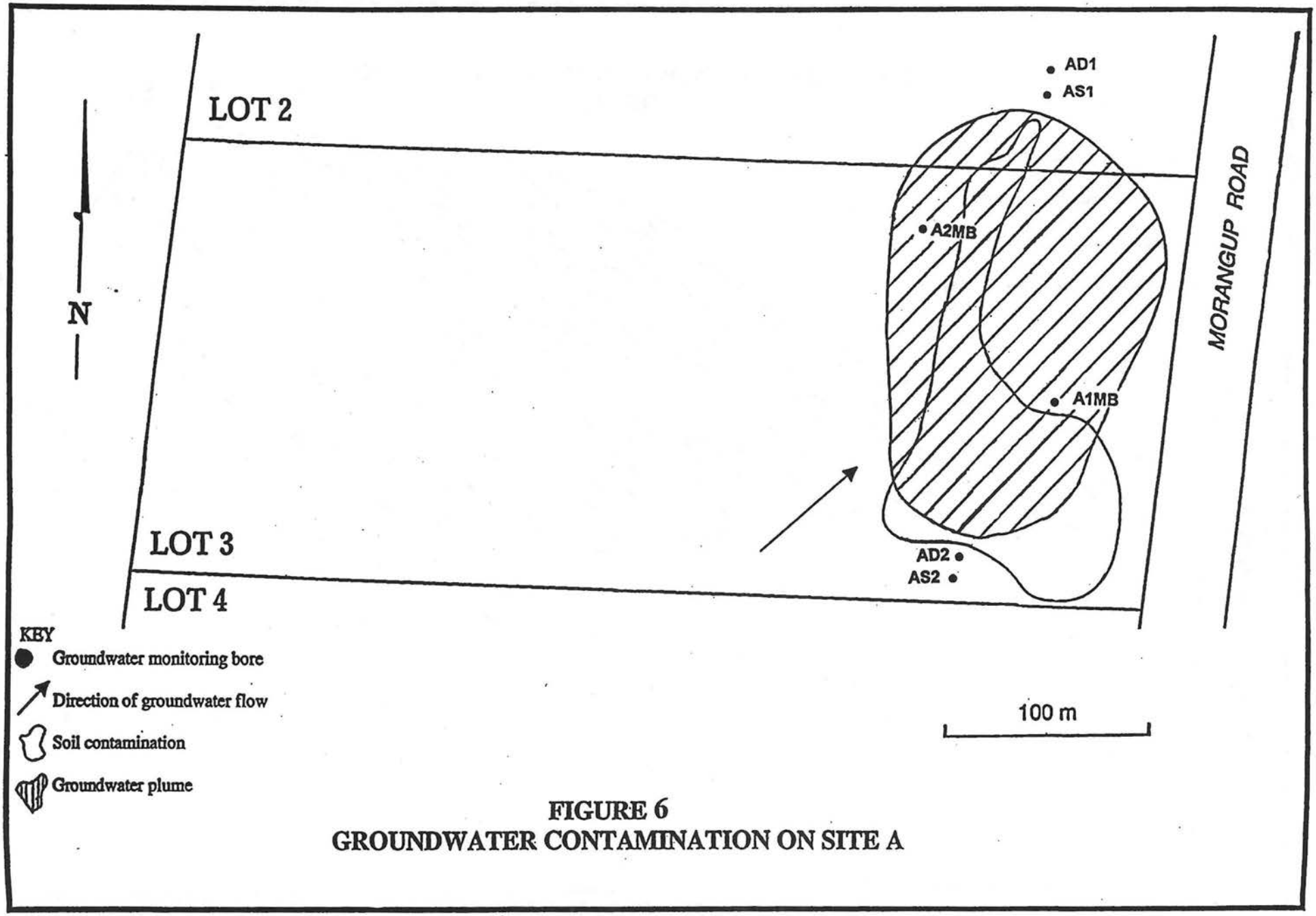


FIGURE 6
GROUNDWATER CONTAMINATION ON SITE A

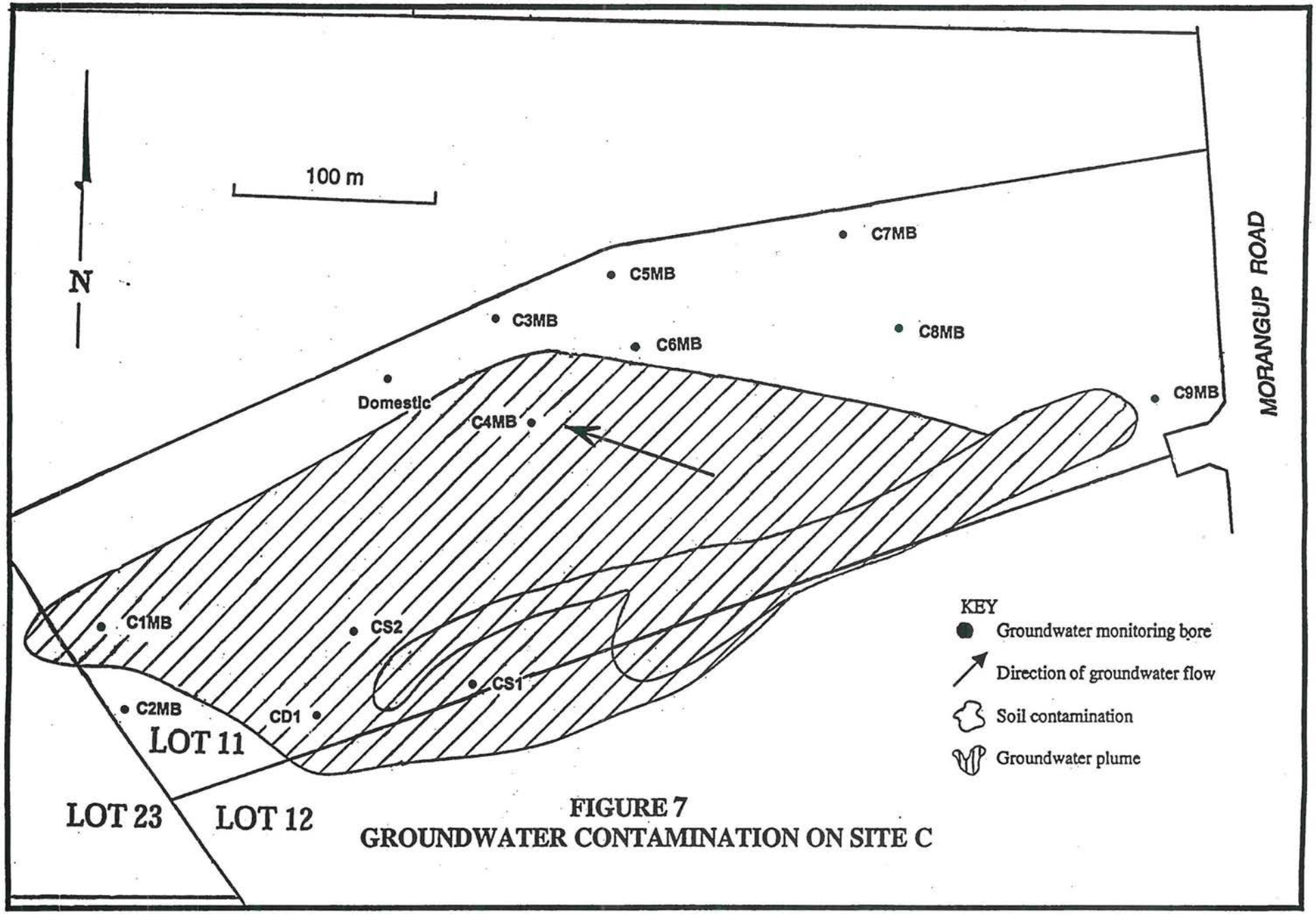


FIGURE 7
GROUNDWATER CONTAMINATION ON SITE C

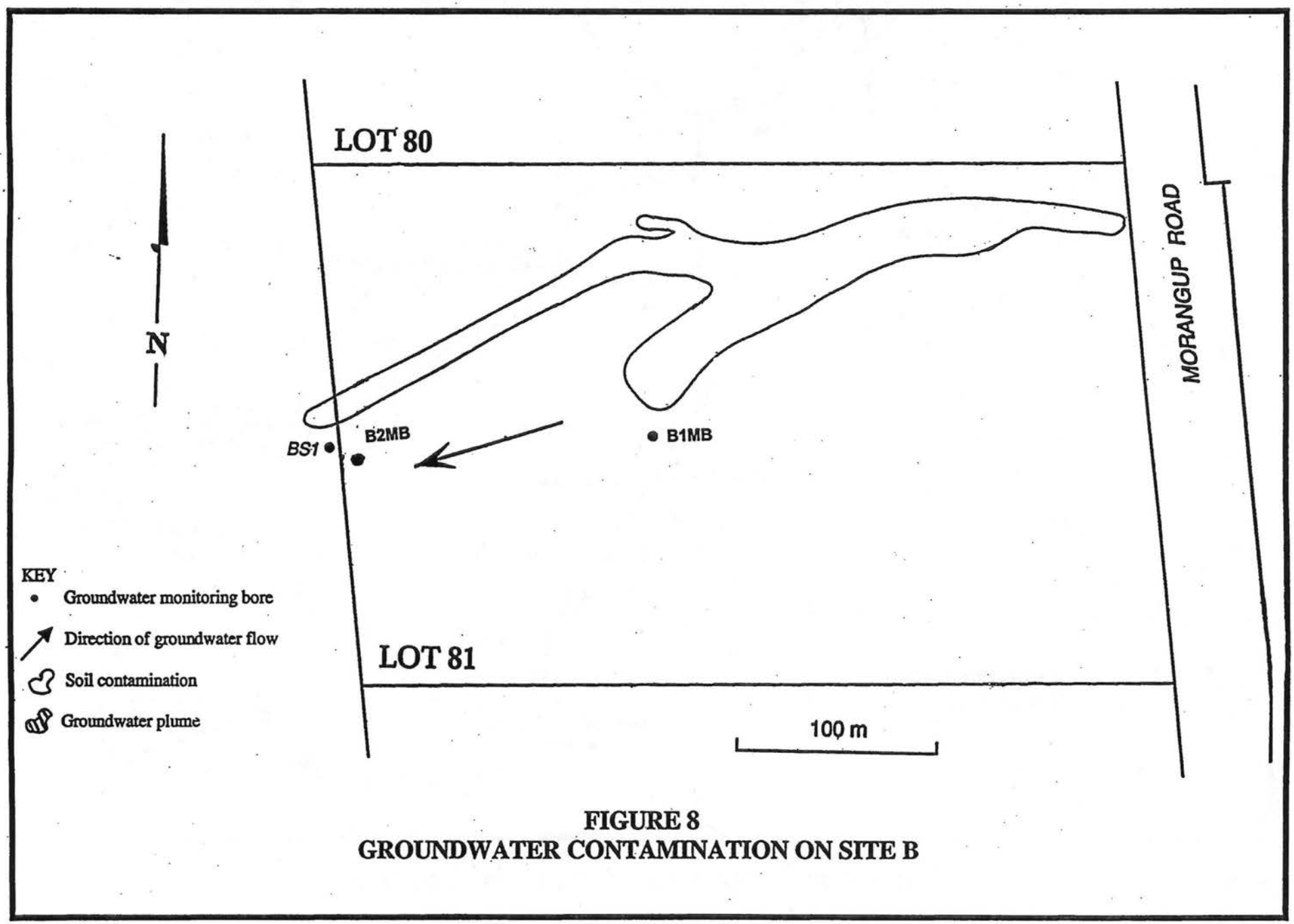


FIGURE 8
GROUNDWATER CONTAMINATION ON SITE B

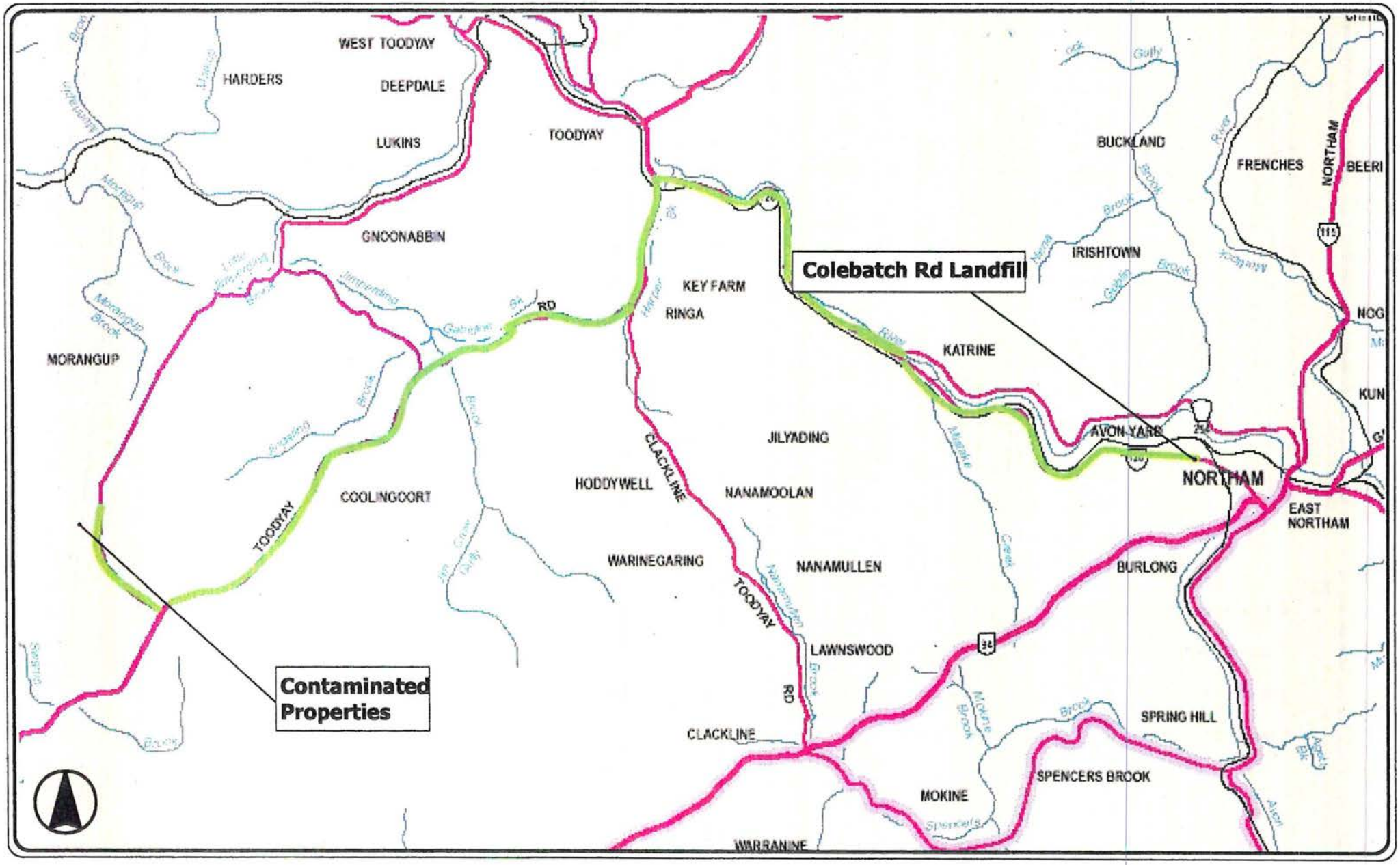


Figure 9. **Proposed Transport Route to Landfill**

APPENDICES

APPENDIX ONE
Approval to Clear Vegetation

DEPARTMENT OF ENVIRONMENTAL PROTECTION

M E M O R A N D U M

To: Catherine Bozanich, A/Manager, Waste Operations Branch

Cc: Mr Shane Sadleir

From: Chris Tallentire, Environmental Officer, Evaluation Division

Subject: **MORANGUP: CLEARING OF NATIVE VEGETATION ASSOCIATED WITH CONTAMINATED SITES**

Date: 28 May 2001

1. A site inspection to the Morangup properties listed below was made 8 November 2000. The inspection was made by Shane Sadleir, Graeme French and Chris Tallentire.

2. Each of the listed properties has an area where the soil profile has been contaminated through the inappropriate dumping of waste material.

Site	Owners / Occupiers	Lot Nos	Area of Property
A	Mr D Dewar	3	10.0 ha
B	Mr D Tancabel	81	10.0 ha
C*	Mr R & and Mrs C Tysoe	11	9.4 ha

contamination at Site C extends marginally onto Lot 12 owned by N & B Skehan and ? & ? Blackie.

3. It is understood that a commitment has been made by Government to rehabilitate the contaminated areas. This will involve the removal of contaminated soil, and replacement with contaminant free soil.

4. It is also understood that through the soil rehabilitation process it may be necessary to clear small areas of native vegetation. Using the Heddle *et al* (1980) vegetation mapping the vegetation type covering the contaminated sites was **'Dwellingup Yalanbee and Hester/Complex in Low to Medium Rainfall'.**

5. Under the *Soil and Land Conservation Act 1945* vegetation is deemed to be notifiable if its clearing will lead to a change in land use, and if its area is greater than one hectare.

6. The vegetation observed during the site visit to Morangup would not be considered 'notifiable', because of its diminished ecological health, and because the areas of notifiable vegetation are less than one hectare.

7. The present condition of most of the vegetation is such that it could not be described as being ecologically self-sustaining. Its ecological health has been compromised by the soil contamination.

8. For each of the properties the area of vegetation that would be cleared in the rehabilitation process is small. However, where the clearing of native vegetation exceeds one hectare, the need to notify the clearing of that vegetation has to be considered.

9. Where it is the intent of the landholders to rehabilitate the land to a vegetation type that is typical of the area and ecologically self-sustaining, then it would be appropriate that commitments to revegetation be managed through the site decontamination and rehabilitation process.

10. It was observed that much of the proposed rehabilitation area includes extended narrow areas, caused by the flow of the liquid contaminant. If clearing is kept within the contaminated areas then this will help ensure that the area of land to be cleared is minimised.

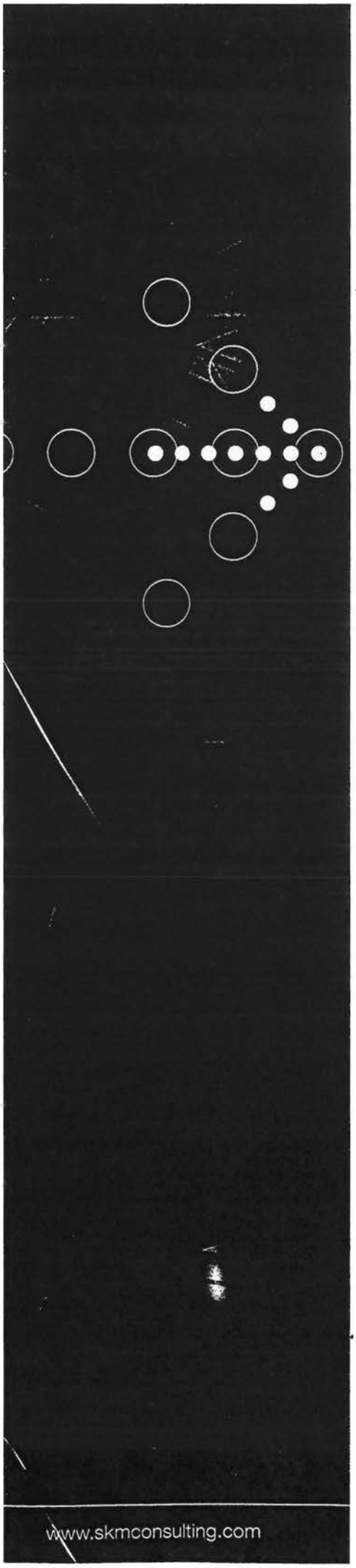
11. Priority must be given in the rehabilitation process to the development of an appropriate revegetation plan. The plan should include a plant species list that only includes plant species that are locally indigenous to the area. To this end it is important that the 'new' soil be as typical as possible of soils naturally occurring in the area.

12. Plant seed stock should be sourced from nearby (within 5 km) areas of native vegetation that are typical of the **'Dwellingup Yalanbee and Hester/Complex in Low to Medium Rainfall'.** This will ensure that all plants are grown from seed of local provenance.

CHRIS TALLENTIRE
ENVIRONMENTAL OFFICER

28 May 2001

APPENDIX TWO
Risk Assessment



Department of Environmental Protection Waste Management Division

Morangup Road, Toodyay, WA
Risk Assessment of Contaminated Sites near Morangup Road, Toodyay

March 2001

SINCLAIR KNIGHT MERZ

www.skmconsulting.com

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1. Executive Summary

Sinclair Knight Merz was commissioned by the Department of Environmental Protection (DEP) to perform a risk assessment of the contamination existing on contaminated sites at Morangup Road, Toodyay.

Groundwater contamination was first reported in 1992 by the owner of Lot 3 Morangup Road after a domestic bore on the property was found to be contaminated with phenolic compounds. There is anecdotal evidence that wood tar wastes from the Wundowie Charcoal Iron and Steel Industry were dumped on the western side of Morangup Road from the 1960s to the 1970s, during State ownership of the plant.

Three principal dumpsites have been identified:

- Site A: Lot 3 Morangup Road, 10.001ha
- Site B: Lot 81 Morangup Road, 10.007ha
- Site C: Lot 11, Morangup Road 9.3885ha

The wood-tar wastes are mixed with natural soil (silty lateritic gravels). The proportion of wood tar in the soil matrix is variable, ranging from complete impregnation of the pore space in the soil (generally near the surface) to a dark grey staining of soil particles at depth. The contaminated soils are strongly hydrophobic and therefore only minimal vegetation growth is possible on contaminated areas.

Previous investigations indicate that contaminants of concern in the soil are:

- Total Phenols: Concentrations ranging from 0.43mg/kg to 96mg/kg
- Leachable Total Phenols: Concentrations ranging from <0.05mg/L to 1.8mg/L
- Total Polycyclic Aromatic Hydrocarbons (PAHs): Concentrations ranging from <2.5mg/kg to 3.1mg/kg

This study was divided into two main tasks:

- Review existing literature and recommend acceptable levels of in total phenols soil and groundwater.
- Apply recognised risk analysis techniques to determine and recommend appropriate Ecological Response Levels for total phenols in surface soils that are protective of the current and future beneficial uses of groundwater.

The scope of work has been expanded to provide an assessment of other phenolic compounds and recommend options for more detailed assessment of other risk pathways which may be required depending on the final remediation approach adopted by the DEP. The assessment of remediation options was outside the scope of the study.

Several pathways were identified, in which sensitive receptors may come into contact with phenol contamination. These are:

- ingestion of contaminated soil;
- inhalation of particulates or windblown dust;
- dermal sorption;
- ingestion of home-grown produce;
- ingestion of contaminated groundwater;
- use of contaminated groundwater for watering of produce or for stockwatering;

- soil erosion or surface run-off from the site causing migration of soil contaminants into nearby water bodies and drains; and
- aquatic ecosystem exposure from groundwater running into nearby creeks and streams.

This study identified the following criteria for soil and groundwater:

- Soil (protective of groundwater):
  - Total phenols not to exceed 9mg/kg
- Groundwater:
  - Drinking, stockwatering and irrigation – total phenols not to exceed 2µg/L
  - Aquatic ecosystem protection – total phenols not to exceed 0.1µg/L

The approach to remediation proposed by the DEP involves the removal of the surface 250mm of contaminated material on the sites. The excavation of soil above the 9mg/kg criteria identified by this study is also recommended to minimise further leaching of contaminants from the soil to groundwater.

However, the removal of the contaminant sources does not affect management requirements for the existing groundwater plume. These could include a moratorium on abstraction, monitoring (of the plume movement and contaminant levels) as well as provision of treatment options or alternate sources to existing bore users. These options for groundwater management would further remove pathways for sensitive receptors to be exposed to contaminants.

In addition, the recommended cleanup criteria will not necessarily return beneficial uses to the owners that are equivalent to adjacent uncontaminated lots. Remaining soil contaminants and contaminants in the groundwater may affect the growth, yield or flavour of produce from deeper-rooted crops.

Results of sampling undertaken by others in parallel with this study, indicated contaminants were also found to occur in caprock underlying the sites. Analysis of caprock samples showed that the highest concentrations and potentially the most mobile contaminants were contained within the caprock. The management of contaminants contained in the caprock was outside the scope of this risk assessment.

2. Introduction

2.1 Background

Groundwater contamination was first reported in 1992 by the owner of Lot 3 Morangup Road after a domestic bore on the property was found to be contaminated with phenolic compounds. There is anecdotal evidence that wood tar wastes from the Wundowie Charcoal Iron and Steel Industry were disposed of on the western side of Morangup Road from the 1960s to the 1970s, during State ownership of the plant.

Three principle disposal sites have been identified (refer **Figure 1**):

- Site A: Lot 3 Morangup Road, 10.001ha
- Site B: Lot 81 Morangup Road, 10.007ha
- Site C: Lot 11, Morangup Road 9.3885ha

The wood-tar wastes are mixed with natural soil (silty lateritic gravels). The proportion of wood tar in the soil matrix is variable, ranging from complete impregnation of the pore space in the soil (generally near the surface) to a dark grey staining of soil particles at depth.

Contaminated soils are strongly hydrophobic and will not allow water penetration even after extensive periods of rainfall. Hence these areas cannot be used for production of crops or to sustain other vegetation including native species.

2.2 Findings of Previous Studies

Previous studies of the site include:

Thorpe Groundwater and Environmental Services. February 2001. *Soil Characterisation and Testing Program for Contaminated Sites near Morangup Road, Toodyay, Western Australia.*

Sinclair Knight Merz. February 2001. *Dust Characterisation and Soil Wetting Program for Contaminated Sites near Morangup Road, Toodyay.*

Thorpe Groundwater and Environmental Services. September 2000. *Advice on a Soil Characterisation and Testing Program for Contaminated Sites near Morangup Road, Toodyay, Western Australia.*

Thorpe Groundwater and Environmental Services. July 2000. *Investigation of Groundwater Contamination at Morangup Road, Toodyay, Western Australia.*

Dames and Moore Group. April 2000. *Assessment of Remediation Options for Contaminated Land on Morangup Road, Toodyay.*

CMPS&F. September 1997. *Morangup Road, Toodyay, Phase 2 Report, Consultancy Services for an Environmental Site Assessment.*

Previous investigations indicate that contaminants of concern are:

- Total Phenols: Concentrations ranging from 0.43mg/kg to 96mg/kg
- Leachable Total Phenols: Concentrations ranging from <0.05mg/L to 1.8mg/L
- Total Polycyclic Aromatic Hydrocarbons (PAHs): Concentrations ranging from <2.5mg/kg to 3.1mg/kg

Studies also show minor levels of polycyclic aromatic hydrocarbons (PAHs) and total petroleum hydrocarbons (TPHs) are present in the surface contamination.

The contaminated soil has been observed to be strongly hydrophobic possibly due to wood tar coating the soil particles. Even after considerable rainfall has occurred most of the contaminated soil remains dry.

Monitoring of groundwater has shown contaminated groundwater below and down-gradient of contaminated soil at Sites A and C, with total phenols up to 190µg/L at Site C. Results do not indicate contamination in groundwater underlying Site B.

2.3 Purpose of This Study

Sinclair Knight Merz was commissioned by the Department of Environmental Protection to perform a risk assessment of the contamination existing on contaminated sites on Morangup Road, Toodyay.

This study as defined in the proposal submitted by Sinclair Knight Merz (November 2000) was divided into two main tasks:

- Review existing literature and recommend acceptable levels of in soil and groundwater.
- Apply recognised risk analysis techniques to determine and recommend appropriate Ecological Response Levels for total phenols in surface soils that are protective of the current and future beneficial uses of groundwater.

The scope of work has been expanded to provide an assessment of other phenolic compounds and recommend options for more detailed assessment of other risk pathways which may be required depending on the final remediation approach adopted by the DEP.

The assessment of remediation options was outside the scope of the study.

2.4 Approach

This risk assessment was performed via a three-step process:

- Characterisation of phenol contamination present in soils and groundwater at the sites including the types of phenols present in both media, the concentrations present, and the lateral and vertical distribution of the contamination.
- A literature review of soil and groundwater guidelines for the phenols of concern. This was undertaken using all available reference sources including any data that was available at relevant websites. Following the review, preliminary remediation goals (adopted criteria) were proposed that represent levels to which the sites should be remediated to minimise the potential for adverse effects to human health or the environment.

- Comparison of the concentrations present in soil and groundwater at the sites with the proposed remediation goals to determine the level of clean up required to render the sites suitable for continued residential/agricultural use. Remediation options proposed by the DEP were also discussed.

2.5 Limitations of this Study

This study has the following limitations:

- This risk assessment does not address contaminants contained within the caprock.
- Sinclair Knight Merz have only assessed remedial options suggested by the DEP as outlined subsequently in this report. No review of other possible options for remediation has been conducted.
- The characterisation of contamination and assessment of pathways and receptors is based on sampling results and supporting reports provided by the DEP.

3. Contaminants and Risk Pathways

3.1 Contaminants of concern and exposure assessment

As discussed in **Section 2.2**, a number of studies have been undertaken to determine the nature and extent of tar residue waste and contaminants in soil and groundwater at the sites. These studies indicate the tar thickness in the soils to be variable at the three sites. Although there are minor levels of PAHs and TPHs in the soil, the main contaminants are phenols (generally alkylated and alkoxylated phenols). No chlorinated phenols were found to be present. The phenols found in the groundwater were generally alkylated phenols only (being the more soluble species present). Further discussion on the specific phenols found in soil and groundwater is presented in **Sections 3.1** and **3.2**.

Generally, phenols are detected in soils and water using a generic test method. This provides a result as 'total phenols'. There are, however, significant differences in the toxicity of phenols. For example, the base compound phenol is about 1000 times less toxic than the substituted phenol, 2,6-dimethylphenol. It is therefore important that any testing for phenols is undertaken so that individual species are identified rather than just a 'total phenols' result being reported.

With phenols having been detected in both soil and groundwater, it is important to consider the potential exposure to these chemicals from various exposure routes via an exposure assessment. There are four elements that form part of an exposure assessment:

- identification of exposure scenarios;
- identification of exposure receptors;
- identification of exposure pathways; and
- estimation of the likely degree of exposure.

For the sites under consideration, the exposure scenario is use of the land for agricultural and residential purposes. There is evidence of the sites being used as hobby farms, with animals grazing and residents growing produce including fruit and vegetables. These land uses are considered to be the most sensitive, where exposure to contaminated soil and groundwater is expected to be greater than for other land-uses, such as commercial or industrial.

Given the sites are being used for agricultural and residential purposes, the main receptors who may potentially come into contact with contaminated soil and groundwater include adult and children residents as well as ecological receptors. Ecological receptors include aquatic species present in the nearby creeks and perhaps livestock, which may be grazed on the land.

Contamination in the soil extends to the caprock below, and in some locations has also infiltrated into the caprock itself. Phenol contamination has also been noted in groundwater at the site. Hence, potential receptors may come into contact with phenol contamination via a number of pathways including:

- ingestion of contaminated soil;
- inhalation of particulates or windblown dust;
- dermal sorption;
- ingestion of home-grown produce;
- ingestion of contaminated groundwater;
- use of contaminated groundwater for watering of produce or for stockwatering;
- soil erosion or surface run-off from the site causing migration of soil contaminants into nearby water bodies and drains; and
- aquatic ecosystem exposure from groundwater running into nearby creeks and streams.

These potential pathways are shown in **Figure 2**.

3.2 Groundwater Analytical Results

While the soil contamination is not expected to result in a significant health effect to users of the site, the contamination in the underlying groundwater could be. According to previous reports, groundwater in the area is used for drinking. Landowners can tap into both shallow and deep groundwater for their domestic water supplies. There is also evidence that groundwater has been used for irrigation and stockwatering purposes. Typical groundwater depths and the direction of groundwater flow from the sites is as follows:

- Site A – depth from 4.5 – 8.3m, flows NE towards Morangup Brook
- Site B – approximate depth of 10.5m, flows W–SW towards the creek line
- Site C – depth from 4.3 – 16.1m, flows W–NW towards a nearby unnamed creek.

The movement of the groundwater off-site has been determined to be very slow and it is not expected that contamination of the creek water would occur in the short term. Even so, if the groundwater eventually discharges into these waterbodies, it is important that any aquatic ecosystems are protected.

The beneficial uses of the groundwater which require protection therefore include:

- drinking water supply;
- irrigation;
- stockwatering; and
- aquatic ecosystems.

Assessment of the groundwater to date has indicated types of phenols present to include alkylated phenols including methyl-, dimethyl-, ethylmethyl- and trimethyl-phenols. To assess whether the concentrations of alkylated phenols present in the groundwater are affecting any of these beneficial uses, a literature survey of published guidelines and standards has been completed and is presented in **Section 4**.

3.3 Soil and Caprock Analytical Results

335 soil and caprock samples were collected and submitted for analysis by Thorpe Groundwater and Environmental Services in 2000. Most of the soils analysed from the three sites have been tested for 'total phenols' rather than individual phenolic species. Soil and caprock analytical results are summarised in **Tables 3.2 to 3.4**. The concentrations found in the surface soils and tar residues appear to range from 0.2mg/kg up to 31mg/kg of total phenols. Concentrations in soil and caprock located beneath the tar generally contained lower concentrations of total phenols, although high concentrations (up to 96 mg/kg) were noted in the caprock.

26 soil/caprock samples were submitted for analysis of individual phenol species. The phenol species tested for individually in the soil included the following:

- phenol;
- 2-methylphenol;
- 4-methylphenol;
- 2-chlorophenol;
- 2,4-dimethylphenol;
- 2,4-dichlorophenol;
- 2,6-dichlorophenol;
- 2,4,6-trichlorophenol;
- 2,4,5-trichlorophenol;
- 2,3,4,6-tetrachlorophenol;
- pentachlorophenol;
- 2-nitrophenol; and
- 4-nitrophenol.

Apart from phenol, the only other species detected were 2-methylphenol, 4-methylphenol and 2,4-dimethylphenol. All these phenols were found in one sample, a caprock sample from location BG19, and one soil sample, a sample from location CG35, was found to contain 2,4-Dimethylphenol.

According to published toxicity data, of all the phenol species characterised as part of the study, 2,4-dimethylphenol is the most toxic. On this basis, results for 2,4-dimethylphenol have been used for risk assessment purposes. The difference between the 'total phenol' results and the aggregated results for the samples tested for selected phenol species is the result of the laboratory procedures used (pers comm Shane Sandlier/Rick Staker and Kim Rogers). The remaining species that make up the difference in concentration are not known but it is probable that, as the contamination is historic and the soil would have been subject to considerable weathering and water washing, the species left in the soil are longer chain species which are not as water-soluble and present lower risk to the groundwater.

Leaching tests were undertaken on the 26 soil/caprock samples described above to determine their potential to leach phenols into the underlying groundwater. Leaching results showed contaminants present in the caprock have the potential to be the main contributor to groundwater contamination. Concentrations of leachable phenols in the caprock were up to 820µg/L. The contribution of contamination from soils was minor in comparison, with leachable phenols from soils at the sites ranging from <0.5µg/L to 1.3µg/L.

Table 3.2: Soil and Caprock Analystical Results - Total Phenols

Test pit ref.	Date sampled	Total depth (mbns)	Depth interval (m)	Soil type (USCS code)	Tar waste thickness (visual) (m)	m East (AMG)	m North (AMG)	Surface elevation (mAHD)	Analysis sample ref.	Duplicate analysis sample ref.	Sample interval (m)	Total phenols (mg/kg)	Moisture content (%)
Site A													
AG1	16/10/2000	0.93	0-0.18	Grey GM	0.18	434234.873	6497627.364	365.392	26		0-0.25	7.1	3.7
			0.18-0.93	Brown GM					27		0.25-0.5	0.26	6.4
AG2	16/10/2000	0.92	0-0.28	Grey GM	0.28	434228.868	6497608.341	365.609	28		0-0.25	3.5	4.6
			0.28-0.92	Brown GM					29		0.25-0.5	0.23	6.4
									30	31	0.5-0.75	0.11 (0.07)	6.2 (6.0)
AG3	16/10/2000	0.91	0-0.18	Grey GM	0.18	434222.956	6497589.159	365.784	32		0-0.25	4.4	4.1
			0.18-0.91	Brown GM					33		0.25-0.5	0.23	6.4
			>0.91	R					34		0.5-0.75	0.12	5.9
AG4	16/10/2000	0.9	0-0.2	Grey GM	0.25-0.85 L	434217.015	6497570.120	365.774	38		0-0.25	2.2	5.4
			0.2-0.85	Brown/Grey GM					39		0.25-0.5	0.59	7.6
			0.85-0.9	Brown GM					40		0.5-0.75	0.47	6
			>0.9	R					41		0.75-0.9	0.13	5.7
AG5	16/10/2000	0.75	0-0.37	Grey GM	0.25-0.37 L	434213.291	6497591.611	365.703	35		0-0.25	3.2	4.6
			0.37-0.75	Brown GM					36		0.25-0.5	0.22	7.4
			>0.75	R					37		0.5-0.75	0.2	6.1
AG6	16/10/2000	0.96	0-0.36	Grey GM	0.36	434241.718	6497582.486	366.048	42		0-0.25	3.8	4.9
			0.36-0.96	Brown GM					43		0.25-0.5	0.35	7.8
				R					44		0.5-0.75	0.14	7.2
AG7	16/10/2000	0.9	0-0.13	Grey GM	0.13	434240.897	6497646.636	365.203	23		0-0.25	1.2	4.5
			0.13-0.9	Brown GM					24		0.25-0.5	0.47	6.4
									25		0.5-0.75	0.31	6.5
AG8	16/10/2000	0.88	0-0.15	Grey GM	0.38	434246.996	6497661.998	365.002	20		0-0.25	2.3	5
			0.15-0.38	Brown/Grey GM					21		0.25-0.5	1.2	8.4
			0.38-0.88	Brown GM					22		0.5-0.75	0.07	7.7
AG9	16/10/2000	1.1	0-0.25	Grey GM	0.9	434253.942	6497685.511	364.791	9		0-0.25	3.4	2.6
			0.25-0.9	Brown/Grey GM					10		0.25-0.5	0.41	6.7
			0.9-1.1	Brown GM					11		0.5-0.75	0.18	5.7
									12		0.75-1.0	0.48	5.8
AG10	16/10/2000	0.81	0-0.14	Grey GM	0.66	434258.940	6497703.928	364.617	6		0-0.25	1.8	4.2
			0.14-0.66	Brown/Grey GM					7		0.25-0.5	0.96	8.9
			0.66-0.81	Brown GM					8		0.66-0.81	0.24	6.5
AG11	16/10/2000	0.9	0-0.2	Grey GM	0.2	434264.362	6497723.657	364.262	4		0-0.25	0.34	4.9
			0.2-0.9	Brown GM					5		0.25-0.5	0.38	7.7
AG12	16/10/2000	0.8	0-0.15	Grey GM	0.15	434270.414	6497741.728	363.825	1		0-0.25	0.15	6.2
			0.15-0.8	Brown GM					2		0.25-0.5	<0.05	7.6
									3		0.5-0.75	0.11	6.8
AG13	16/10/2000	0.88	0-0.15	Grey GM	0.15	434254.464	6497622.625	365.620	66		0-0.25	8.8	4.1
			0.15-0.88	Brown GM					67		0.25-0.5	0.49	7.4
AG14	16/10/2000	0.94	0-0.2	Grey GM	0.2	434248.120	6497602.645	365.869	63		0-0.25	0.38	3.4
			0.2-0.94	Brown GM					64	65	0.25-0.5	0.29 (0.47)	5 (5.4)
AG15	16/10/2000	0.87	0-0.14	Grey GM	0.14	434271.700	6497610.840	366.417	68		0-0.25	4.2	4.4
			0.14-0.87	Brown GM					69		0.25-0.5	0.72	6.4
AG16	16/10/2000	1.1	0-0.2	Grey GM	0.2	434289.817	6497602.631	367.206	70		0-0.25	2.8	7.3
			0.2-1.1	Brown GM					71		0.25-0.5	0.76	8
									72		0.5-0.75	0.66	8
AG17	16/10/2000	1.1	0-0.6	Grey GM	0.2-0.6 L	434259.917	6497572.538	366.695	45		0-0.25	6	5.1
			0.6-1.1	Brown GM					46		0.25-0.5	1.4	5.2
									47	48	0.5-0.75	0.31 (0.19)	5.4 (5.4)
AG18	16/10/2000	0.8	0-0.18	Grey GM	0.18	434265.744	6497591.476	366.587	58		0-0.25	6.1	3.6
			0.18-0.8	Brown GM					62		0.25-0.5	3.9	4.8
AG19	16/10/2000	0.9	0-0.24	Grey GM	0.24	434307.933	6497594.260	368.168	73		0-0.25	6.8	4.5
			0.24-0.9	Brown GM					74		0.25-0.5	0.61	6
AG20	16/10/2000	0.95	0-0.25	Grey GM	0.25	434278.221	6497564.563	367.461	49		0-0.25	10.000	4.8
			0.25-0.95	Brown GM					50		0.25-0.5	0.43	6
									51		0.5-0.75	0.26	6.2
AG21	16/10/2000	0.8	0-0.55	Grey GM	0.55	434283.853	6497583.542	367.377	59		0-0.25	9.400	5.8
			0.55-0.8	Brown GM					60		0.25-0.5	1.2	6.6
									61		0.5-0.75	0.68	6.8
AG22	16/10/2000	0.9	0-0.15	Grey GM	0.15	434296.666	6497556.214	368.344	52		0-0.25	6.7	6
			0.15-0.9	Brown GM					53		0.25-0.5	0.4	8.8
AG23	16/10/2000	0.84	0-0.15	Grey GM	0.15	434302.604	6497575.120	368.445	56		0-0.25	3.5	6.9
			0.15-0.84	Brown GM					57		0.25-0.5	0.58	7.1
AG24	16/10/2000	0.71	0-0.14	Grey GM	0.14	434310.882	6497571.601	368.808	54		0-0.25	2	7.2
			0.14-0.71	Brown GM					55		0.25-0.5	0.48	7
AG25	16/10/2000	0.84	0-0.1	Brown GM	0	434273.434	6497699.711	364.591	15		0-0.25	0.64	6
			0.1-0.8	Brown GM					16	17	0.25-0.5	0.25 (0.52)	7.3 (6.8)
AG26	16/10/2000	0.83	0-0.15	Brown GM	0	434241.721	6497710.866	364.532	13		0-0.25	1.4	6.5
			0.15-0.83	Brown GM					14		0.25-0.5	0.17	6.6
AG27	16/10/2000	0.8	0-0.14	Brown GM	0	434275.921	6497633.372	365.951	18		0-0.25	0.69	5.1
			0.14-0.8	Brown GM					19		0.25-0.5	0.27	6.7
Site B													
BG1	19/10/2000	0.24	0-0.24	Grey GW	>0.24	433931.526	6496526.881	359.165	277		0-0.24	15.000	2.8
			>0.24	R									
BG2	19/10/2000	0.32	0-0.16	Grey GW	0.16	433947.744	6496549.818	360.085	275		0-0.25	5.8	2.5
			0.16-0.32	Brown GW					276		0.25-0.32	2	3.5
			>0.32	R									
BG3	19/10/2000	0.51	0-0.16	Grey GW	0.16	433976.147	6496558.028	360.885	273		0-0.25	1.3	4.6
			0.16-0.51	Brown GW					274		0.25-0.5	1.5	3.7
			>0.51	R									
BG4	19/10/2000	0.45	0-0.3	Grey GW	0.15-0.3 L	434002.015	6496565.466	361.795	271		0-0.25	2.7	2.2
			0.3-0.45	Brown GW					272		0.25-0.45	2.4	5
			>0.45	R									
BG5	19/10/2000	0.18	0-0.18	Grey/Brown GW	>0.18	434031.746	6496565.700	362.765	267		0-0.18	5.8	3.9
			>0.18	R									
BG6	19/10/2000	0.16	0-0.16	Grey/Brown GW	>0.16	434058.586	6496577.869	363.575	266		0-0.16	6.3	2.1
			>0.16	R									
BG7	19/10/2000	0.25	0-0.07	Grey GW	0.07	434084.300	6496591.015	364.355	262		0-0.25	12.000	1.6
			0.07-0.25	Brown GW									
			>0.25	R									
BG8	19/10/2000	0.47	0-0.17	Grey GW	0.17	434004.833	6496552.242	361.605	268		0-0.25	5	3
			0.17-0.47	Brown GW					269		0.25-0.47	1.9	5.4
			>0.47	R									
BG9	19/10/2000	0.26	0-0.12	Grey GW	0.26	433980.871	6496534.132	360.365	270		0-0.25	7.1	2.7
			0.12-0.26	Grey/Brown GW									
			>0.26	R									

Test pit ref.	Date sampled	Total depth (mbns)	Depth interval (m)	Soil type (USCS code)	Tar waste thickness (visual) (m)	m East (AMG)	m North (AMG)	Surface elevation (mAHD)	Analysis sample ref.	Duplicate analysis sample ref.	Sample interval (m)	Total phenols (mg/kg)	Moisture content (%)
BG10	19/10/2000	0.56	0-0.2	Grey GW	0.2	434089.693	6496540.112	363.735	279		0-0.25	4.1	2.6
			0.2-0.56	Brown/Grey GW					280	281	0.25-0.5	1.3 (1.2)	5.6 (5.8)
			>0.56	R									
BG11	18/10/2000	0.96	0-0.85	Grey GW	0.32-0.85 L	434114.729	6496556.475	364.775	249		0-0.25	[illegible]	2.8
			0.85-0.96	Brown GW					250		0.25-0.5	0.44	6.5
									251		0.5-0.75	0.53	6.2
									252		0.75-0.96	0.39	6.4
BG12	18/10/2000	0.57	0-0.57	Grey GW		434139.776	6496573.576	365.745	238		0-0.25	3.6	2.9
			>0.57	Grey GW (hard)					239		0.25-0.5	0.5	6
	31/10/2000	1.25	0-0.6	Grey GW	0.6				304		0.5-0.75	1.4	5.4
			0.6-1.25	Brown GW					305	306	0.75-1.0	0.46 (0.48)	5.7 (5.9)
BG13	18/10/2000	0.5	0-0.5	Grey GW	>0.5	434164.875	6496590.630	366.775	223		0-0.25	3.7	5.5
			>0.5	Grey GW (hard)					224		0.25-0.5	2	6.5
	31/10/2000	1.75	0-0.75	Grey GW	1.3				300		0.5-0.75	2.4	5.5
			0.75-1.3	Grey/brown GW					301		0.75-1.3	5.6	6.9
			1.3-1.75	Brown GW					302		1.3-1.5	3.3	6.9
									303		1.5-1.75	0.79	5.2
BG14	18/10/2000	0.75	0-0.2	Brown GP	0	434189.993	6496607.442	367.745	200		0-0.25	0.45	4.8
			0.2-0.75	Brown GW					201	202	0.25-0.5	0.18 (0.18)	6.1 (5.6)
BG15	18/10/2000	0.51	0-0.24	Grey GW	0-0.24	434214.372	6496623.843	368.855	190		0-0.25	4.1	3.9
			0.24-0.51	Brown GW	L				191		0.25-0.5	0.31	4.8
BG16	18/10/2000	0.57	0-0.57	Grey/Brown GW		434220.593	6496616.316	368.865	188		0-0.25	4.9	5.1
			>0.57	Grey GW (hard)					189		0.25-0.5	2.4	6
		0.85	0-0.6	Grey/Brown GW	0.6				292		0.4-0.6	[illegible]	4.5
			0.6->0.85	R									
BG17	18/10/2000	0.26	0-0.26	Grey GW		434223.015	6496613.560	368.945	187		0-0.25	5	4.2
			>0.26	Grey GW (hard)									
	31/10/2000	0.65	0-0.4	Grey GW	>0.4				291		0.25-0.4	3.3	2.9
			0.4->0.65	R									
BG18	18/10/2000	0.44	0-0.44	Grey GW	>0.44	434234.859	6496600.931	369.055	185		0-0.25	2.6	7.2
			>0.44	R					186		0.25-0.44	3.7	12
BG19	18/10/2000	0.4	0-0.4	Grey GW		434239.778	6496593.258	369.365	183		0-0.25	8.2	6.3
			>0.4	Grey GW (hard)					184		0.25-0.4	6.8	7.7
	31/10/2000	1	0-0.7	Grey GW	>0.7				289		0.5-0.7	5.4	3.6
			0.7->1.0	R					290		0.75-1.0	[illegible]	5
BG20	18/10/2000	0.49	0-0.19	Brown GP	0	434206.104	6496632.912	368.445	192		0-0.25	0.65	5.3
			0.19-0.49	Brown GW					193		0.25-0.49	0.31	6
BG21	18/10/2000	0.72	0-0.42	Grey GW	0.42	434213.555	6496575.301	368.185	211		0-0.25	8.9	5.5
			0.42-0.72	Brown GW					212		0.25-0.5	1.3	6.8
									213		0.5-0.72	0.28	6.3
BG22	18/10/2000	0.55	0-0.22	Brown GP	0	434219.248	6496567.316	368.315	214		0-0.25	0.6	5.7
			0.22-0.55	Brown GW					215		0.25-0.5	0.43	7
BG23	18/10/2000	0.77	0-0.24	Grey GW	0.24	434207.752	6496583.269	368.015	209		0-0.25	0.31	3.3
			0.24-0.77	Brown GW					210		0.25-0.5	0.16	6.9
BG24	18/10/2000	0.97	0-0.15	Grey/Brown GW	0.15	434202.114	6496591.477	367.975	207		0-0.25	0.5	5.2
			0.15-0.97	Brown GW					208		0.25-0.5	0.2	5.5
BG25	18/10/2000	0.88	0-0.56	Grey GW	0.14-0.56 L	434196.024	6496599.454	367.895	203		0-0.25	[illegible]	5
			0.56-0.88	Brown GW					204		0.25-0.5	[illegible]	7.3
									205		0.5-0.75	0.59	6.9
									206		0.75-0.88	0.19	6
BG26	18/10/2000	0.74	0-0.56	Grey GW	0.1-0.56 L	434184.089	6496615.447	367.735	197		0-0.25	4.2	4.8
			0.56-0.74	Brown GW					198		0.25-0.5	1.1	6.3
									199		0.5-0.74	0.23	5.7
BG27	18/10/2000	0.75	0-0.52	Grey GW	0.52 L	434179.078	6496621.802	367.535	194		0-0.25	6.9	7
			0.52-0.75	Brown GW					195		0.25-0.5	1.5	7.4
									196		0.5-0.75	0.31	5.2
BG28	18/10/2000	0.63	0-0.2	Grey GW	0.2	434174.952	6496573.378	366.745	219		0-0.25	0.65	4.8
			0.2-0.63	Brown GW					220		0.25-0.5	0.61	5.7
BG29	18/10/2000	0.4	0-0.4	Grey GM		434169.937	6496582.000	366.825	221		0-0.25	6.8	5.5
			>0.4	Grey GM (hard)					222		0.25-0.4	5.1	8.6
	31/10/2000	3	0-1.25	Grey GM	2.25				293		0.75-1.00	2	8.5
			1.25-2.0	Grey/Brown GM					294		1.0-1.25	7.8	9.9
			2.0-2.25	Brown/Grey GM					295		1.25-1.5	1.8	9.5
			2.25-2.9	Brown GM					296		1.5-2.0	0.93	6.4
			2.9-3.0	R					297		2.0-2.25	0.53	5.5
									298		2.25-2.5	1.6	5
									299		2.5-2.75	0.31	4.8
BG30	18/10/2000	0.57	0-0.2	Grey GW	0.2	434179.635	6496564.820	366.855	216		0-0.25	6.2	4.2
			0.2-0.57	Brown GW					217	218	0.25-0.5	0.31 (0.23)	5.6 (5.0)
BG31	18/10/2000	0.62	0-0.16	Brown GP	0	434160.023	6496599.056	366.675	225		0-0.25	0.64	4.7
			0.16-0.62	Brown GW					226		0.25-0.5	0.35	6.3
BG32	18/10/2000	0.52	0-0.13	Brown GP	0	434155.562	6496607.917	366.505	227		0-0.25	1.8	3.5
			0.13-0.52	Brown GW					228		0.25-0.5	0.21	5.3
BG33	18/10/2000	0.45	0-0.14	Brown GP	0	434147.769	6496623.161	366.335	229		0-0.25	0.41	5.5
			0.14-0.45	Brown GW					230		0.25-0.45	0.14	6.5
			>0.45	R									
BG34	18/10/2000	0.84	0-0.4	Grey GW	0.4	434142.791	6496564.525	365.685	240		0-0.25	6.7	2.6
			0.4-0.84	Brown GW					241		0.25-0.5	1.2	6.8
									242		0.5-0.75	0.72	5.3
BG35	18/10/2000	0.63	0-0.15	Grey GW	0.15	434148.136	6496555.185	365.615	243		0-0.25	0.42	3.7
			0.15-0.63	Brown GW					244	245	0.25-0.5	0.44 (0.39)	4.8 (5.5)
BG36	18/10/2000	0.76	0-0.76	Grey GW	0.34->0.76 L	434135.532	6496582.528	365.685	235		0-0.25	5.2	4.7
			>0.76	R					236		0.25-0.5	1.4	6.7
									237		0.5-0.75	2.2	6
BG37	18/10/2000	0.61	0-0.2	Brown GP	0	434127.210	6496602.316	365.465	231		0-0.25	0.46	4.8
			0.2-0.61	Brown GW					232		0.25-0.5	0.37	5.3
BG38	18/10/2000	0.59	0-0.18	Brown GP	0	434131.932	6496592.708	365.555	233		0-0.25	0.52	4.7
			0.18-0.59	Brown GW					234		0.25-0.5	0.25	6.4
BG39	18/10/2000	0.77	0-0.77	Grey GW		434120.910	6496549.333	364.925	246		0-0.25	6.1	3.2
			>0.77	Grey GW (hard)					247		0.25-0.5	0.35	5.3
	31/10/2000								248		0.5-0.75	3.1	7.6
		1.75	0-1.4	Grey/Brown GW	1.4				307		0.75-1.1	8.7	7.4
			1.4-1.75	Brown GW					308		1.1-1.5	1	5.1
									309		1.5-1.75	0.29	4.6
BG40	18/10/2000	0.66	0-0.14	Brown GP	0	434107.225	6496563.100	364.575	253		0-0.25	0.56	4.6
			0.14-0.66	Brown GW					254		0.25-0.5	0.5	5.2
BG41	18/10/2000	0.76	0-0.44	Grey/Brown GW	0.44	434100.554	6496570.895	364.545	255		0-0.25	[illegible]	1.8
			0.44-0.76	Brown GW					256		0.25-0.5	1.5	4.3
									257		0.5-0.75	0.43	5

Test pit ref.	Date sampled	Total depth (mbns)	Depth interval (m)	Soil type (USCS code)	Tar waste thickness (visual) (m)	m East (AMG)	m North (AMG)	Surface elevation (mAHD)	Analysis sample ref.	Duplicate analysis sample ref.	Sample interval (m)	Total phenols (mg/kg)	Moisture content (%)
BG42	18/10/2000	0.62	0-0.18	Brown GP	0	434094.733	6496578.746	364.345	258		0-0.25	0.45	4
			0.18-0.62	Brown GW					259		0.25-0.5	0.43	16
BG43	18/10/2000	0.35	0-0.35	Grey/Brown GW	>0.35	434078.756	6496597.587	364.405	263		0-0.25	4.6	2.8
			>0.35	R					264	265	0.25-0.35	2.3 (1.3)	6.3 (6.7)
BG44	18/10/2000	0.55	0-0.2	Brown GP	0	434089.725	6496584.927	364.355	260		0-0.25	0.7	1.9
			0.2-0.55	Brown GW					261		0.25-0.5	0.5	5
			>0.55	R									
BG45	19/10/2000	0.63	0-0.13	Grey GW	0.13	434099.935	6496522.680	363.785	284		0-0.25	3.2	4.6
			0.13-0.63	Brown GW					285		0.25-0.5	0.32	6.6
			>0.63	R					286		0.5-0.63	0.17	5.1
BG46	19/10/2000	0.27	0-0.13	Grey GW	0.13	434094.726	6496531.486	363.785	283		0-0.25	0.97	2.8
			0.13-0.27	Brown GW									
			>0.27	R									
BG47	19/10/2000	0.32	0-0.09	Brown GP	0	434085.128	6496548.618	363.795	278		0-0.25	0.79	5
			0.09-0.32	Brown GW									
			>0.32	R									
BG48	19/10/2000	0.3	0-0.3	Grey GW	>0.3	434080.067	6496557.475	363.895	282		0-0.25	6.9	4.1
			>0.3	R									
BG49	19/10/2000	0.13	0-0.13	Grey GW	>0.13	434080.715	6496514.280	363.345	287		0-0.13	3.8	1.1
			>0.13	R									
BG50	19/10/2000	0.2	0-0.2	Grey GW	>0.2	434063.106	6496508.511	362.215	288		0-0.2	5	3.4
			>0.2	R									
Site C													
CG1	17/10/2000	1	0-1	Grey/Brown GW		434307.379	6495644.186	355.906	125		0-0.25	1.6	4.2
			>1	Grey GW (hard)					126		0.25-0.5	0.98	6.5
									127		0.5-0.75	2.9	9
									128		0.75-1.0	6.6	8.4
	1/11/2000	2.25	0-1.6	Grey/Brown GW	1.6				341		1.0-1.25	4.1	6.3
			1.6-2.25	Brown GW					342		1.25-1.5	3.1	7.9
									343		1.5-1.75	1.7	5.8
									344		1.75-2.0	0.61	5.8
									345		2.0-2.25	0.25	5.3
CG2	17/10/2000	0.75	0-0.75	Grey GW		434281.654	6495627.860	354.366	113		0-0.25	2.8	6.5
			>0.75	Grey GW (hard)					114		0.25-0.5	1.8	10
									115		0.5-0.75	1.6	9.2
	1/11/2000	1.6	0-1.4	Grey GW	1.4				346		0.75-1.0	4.9	6.1
			1.4-1.6	Brown GW					347		1.0-1.25	4.4	6.1
			>1.6	R					348		1.25-1.5	1.2	7.8
									349		1.5-1.6	0.86	5.6
CG3	17/10/2000	0.87	0-0.87	Grey GW	0.4->0.87 L	434255.476	6495613.546	353.150	109		0-0.25	[illegible]	2.9
			>0.87	R					110		0.25-0.5	1.4	5.6
									111		0.5-0.75	1.8	6.3
									112		0.75-0.87	1.3	10
CG4	17/10/2000	0.75	0-0.75	Grey GW	>0.75	434229.210	6495599.196	351.969	156		0-0.25.	4.6	3.9
			>0.75	R					157		0.25-0.5	1.8	9.7
									158		0.5-0.75	2.3	7.4
CG5	17/10/2000	0.68	0-0.2	Grey GW	0.2	434202.973	6495584.664	350.957	166		0-0.25	5	3.1
			0.2-0.68	Brown GW					167		0.25-0.5	0.49	5
CG6	17/10/2000	0.52	0-0.12	Grey GW	0.12	434176.475	6495570.024	349.910	152		0-0.25	1.2	4.6
			0.12-0.52	Brown GW					153		0.25-0.52	0.26	6.9
CG7	17/10/2000	0.5	0-0.5	Grey/Brown GW	0.17->0.5 L	434150.282	6495555.810	348.850	148		0-0.25	8.7	2.8
			>0.5	R					149		0.25-0.5	3.9	5.9
CG8	17/10/2000	0.51	0-0.2	Brown/Grey GW	0.2	434118.946	6495547.413	347.515	150		0-0.25	1.6	4.6
			0.2-0.51	Brown GW					151		0.25-0.51	0.25	5.5
CG9	17/10/2000	0.74	0->0.74	Grey/Brown GW		434312.337	6495633.898	355.951	129		0-0.25	3.5	4.8
			>0.74	Grey GW (hard)					130		0.25-0.5	0.84	7.3
									131		0.5-0.74	0.99	9
	1/11/2000	2.25	0-1.0	Grey/Brown GW	1.1				329		0.75-1.00	1.6	5.9
			1.0-1.1	Brown/Grey GW					330		1.0-1.25	1.8	6.9
			1.1-2.25	Brown GW					331		1.25-1.5	1.9	8.6
									332		1.5-1.75	1.6	5.9
									333		1.75-2.0	1.3	6.6
									334	335	2.0-2.25	0.77 (0.72	6 (5.9)
CG10	17/10/2000	0.76	0-0.76	Grey/Brown GW		434316.089	6495625.758	355.888	132		0-0.25	4.1	5.2
			>0.76	Grey GW (hard)					133		0.25-0.5	1.4	7.1
									134		0.5-0.76	1.7	8
	1/11/2000	1.7	0-1.6	Grey/Brown GW	1.6				336		0.75-1.0	1.4	7
			1.6-1.7	Brown GW					337		1.0-1.25	2	7
									338		1.25-1.5	5	7.9
									339	340	1.5-1.7	0.93 (0.78)	5.5 (5.9)
CG11	17/10/2000	0.9	0-0.15	Grey GW	0.15	434304.124	6495652.221	355.915	120		0-0.25	4.9	2.9
			0.15-0.9	Brown GW					121		0.25-0.5	0.48	6.8
CG12	17/10/2000	0.85	0-0.85	Grey GW	0.38->0.85 L	434286.912	6495619.388	354.453	137		0-0.25	4.1	5
			>0.85	R					138		0.25-0.5	0.72	18
									139		0.5-0.75	2	11
									140		0.75-0.85	1.7	11
CG13	17/10/2000	0.84	0-0.84	Grey GW		434276.246	6495636.389	354.381	116		0-0.25	3.9	4.8
			>0.84	Grey GW (hard)					117		0.25-0.5	1.8	6.5
									118		0.5-0.75	1.4	6.4
									119		0.75-0.84	1.5	7
	1/11/2000	1.5	0-1.1	Grey GW	1.1				350		0.75-1.00	2.7	7
			1.1-1.2	Grey/Brown GW					351		1.0-1.25	1.5	6.1
			1.2-1.5	Brown GW					352	353	1.25-1.5	1.3 (1.4)	6.3 (6.6)
CG14	17/10/2000	0.9	0-0.7	Grey GW	0.4-0.7 L	434260.950	6495606.615	353.127	141		0-0.25	2.4	3.2
			0.7-0.9	Brown GW					142		0.25-0.5	1.7	6.2
									143		0.5-0.75	1.3	5.2
									144		0.75-0.9	0.19	4.8
CG15	17/10/2000	0.7	0-0.5	Grey GW	0.2-0.5 L	434249.267	6495622.579	353.107	106		0-0.25	3.3	6
			0.5-0.7	Brown GW					107		0.25-0.5	1.4	6
									108		0.5-0.7	0.51	4.6
CG16	17/10/2000	0.5	0-0.5	Grey GW	>0.5	434234.230	6495591.231	352.016	154		0-0.25	6.1	3.7
			>0.5	R					155		0.25-0.5	3.2	6.6
CG17	17/10/2000	0.8	0-0.5	Grey GW	0.2-0.5 L	434223.081	6495608.059	351.884	102		0-0.25	4.3	5.7
			0.5-0.8	Brown GW					103		0.25-0.5	1.3	6.3
									104	105	0.5-0.8	0.25 (0.67)	5 (5.4)
CG18	17/10/2000	0.8	0-0.7	Grey GW	0.4-0.7 L	434197.690	6495593.022	351.004	99		0-0.25	2.5	4.6
			0.7-0.8	Brown GW					100		0.25-0.5	1.1	5.9
									101		0.5-0.8	0.92	7.9

Test pit ref.	Date sampled	Total depth (mbns)	Depth interval (m)	Soil type (USCS code)	Tar waste thickness (visual) (m)	m East (AMG)	m North (AMG)	Surface elevation (mAHD)	Analysis sample ref.	Duplicate analysis sample ref.	Sample interval (m)	Total phenols (mg/kg)	Moisture content (%)
CG19	17/10/2000	0.8	0-0.4	Grey GW	0.2-0.4 L	434192.078	6495601.364	350.868	95		0-0.25	2.7	3.5
			0.4-0.8	Brown GW					96		0.25-0.5	1.6	6.5
									97	98	0.5-0.8	0.72 (0.67)	6.6 (6.5)
CG20	17/10/2000	0.6	0-0.55	Grey GW	0.15-0.55 L	434206.215	6495579.872	351.087	168		0-0.25	12	3.5
			0.55-0.6	Brown GW					169		0.25-0.5	6.6	5.6
			>0.6	R					170		0.5-0.6	0.66	4.9
CG21	17/10/2000	0.37	0-0.37	Grey GW	>0.37	434170.796	6495578.052	349.842	164		0-0.25	31	3.8
			0-0.37	Grey GW	>0.38	434171.796	6495579.052	350.842	164R*		0-0.25	31	3.8
			>0.37	R					165		0.25-0.37	4.7	5.8
			>0.37	R					164R*		0.25-0.37	4.7	5.8
CG22	17/10/2000	0.89	0-0.89	Grey GW	0.2->0.89 L	434164.997	6495586.175	349.726	91		0-0.25	3.1	6.7
			>0.89	R					92		0.25-0.5	2.2	14
									93		0.5-0.75	1.3	7.6
									94		0.75-0.89	5.5	9.8
CG23	17/10/2000	0.5	0-0.5	Grey GW	>0.5	434156.178	6495598.017	349.491	89		0-0.25	13	6.5
			>0.5	R					90		0.25-0.5	4	11
CG24	17/10/2000	0.32	0-0.1	Grey GW	0.1	434144.015	6495563.150	348.666	162	163	0-0.25	4.6 (6.9)	4.1 (4.5)
			0.1-0.32	Brown GW									
			>0.32	R									
CG25	17/10/2000	0.31	0-0.31	Grey GW	>0.31	434139.661	6495568.327	348.580	161		0-0.31	9.9	6.3
			>0.31	R									
CG26	17/10/2000	0.42	0-0.18	Grey GW	0.18	434146.823	6495586.026	349.009	87		0-0.25	1.8	4
			0.18-0.42	Grey/Brown GW					88		0.25-0.42	0.71	5.6
			>0.42	R									
CG27	17/10/2000	0.53	0-0.2	Brown GP	0	434109.983	6495551.823	347.167	159		0-0.25	1.5	4.6
			0.2-0.53	Brown GW					160		0.25-0.5	0.61	6.7
CG28	17/10/2000	0.55	0-0.55	Grey GW	>0.55	434127.991	6495588.497	348.260	85		0-0.25	2.2	7.3
			>0.55	R					86		0.25-0.55	0.9	10
CG29	17/10/2000	0.36	0-0.36	Grey GW	0.15->0.36 L	434098.779	6495582.664	346.908	83		0-0.25	6.5	3.4
			>0.36	R					84		0.25-0.36	2.4	5.1
CG30	17/10/2000	0.38	0-0.38	Grey/Brown GW	>0.38	434071.612	6495573.798	345.473	81		0-0.25	1.9	3.4
			>0.38	R					82		0.25-0.38	1.8	5.4
CG31	17/10/2000	0.22	0-0.22	Grey/Brown GW	>0.22	434043.516	6495563.416	343.997	79	80	0-0.25	5.9 (2.5)	4.8 (5.6)
			>0.22	R									
CG32	17/10/2000	0.4	0-0.4	Grey GW	>0.4	434014.690	6495555.591	342.189	77		0-0.25	7.7	3.1
			>0.4	R					78		0.25-0.4	0.78	4.2
CG33	17/10/2000	0.6	0-0.6	Grey/Brown GW	0.2->0.6 L	433986.092	6495551.006	340.168	75		0-0.25	3.2	4.2
			>0.6	R					76		0.25-0.5	3.3	6.4
CG34	17/10/2000	0.57	0-0.57	Grey GW		434324.316	6495642.329	356.721	176		0-0.25	2.4	4.8
			>0.57	Grey GW (hard)					177		0.25-0.5	1.9	11
	1/11/2000	1.6	0-1.3	Grey GW	1.3				325		0.5-0.75	5.4	7.3
			1.3-1.6	Brown GW					326		0.75-1.0	4.1	6
									327		1.0-1.25	3.1	6.9
									328		1.25-1.6	0.76	5.9
CG35	18/10/2000	0.51	0-0.51	Grey GW		434318.621	6495649.888	356.615	174		0-0.25	2.5	5.5
			>0.51	Grey GW (hard)					175		0.25-0.5	4.8	12
	1/11/2000	1.6	0-1.3	Grey GW	1.55				320		0.5-0.75	17	8.7
			1.3-1.55	Grey/Brown GW					321		0.75-1.0	6.4	6.4
			1.55-1.6	Brown GW					322		1.0-1.25	8	8.2
			>1.6	R					323		1.25-1.5	1.6	9.4
									324		1.5-1.6	7.5	4.8
CG36	18/10/2000	0.75	0-0.54	Grey GW	0.12-0.54 L	434317.277	6495659.799	356.763	171		0-0.25	8	4.9
			0.54-0.75	Brown GW					172		0.25-0.5	3.8	6.8
									173		0.5-0.75	0.85	3.6
CG37	17/10/2000	0.63	0-0.11	Grey GW	0.11	434351.853	6495666.467	358.628	180		0-0.25	2	5.4
			0.11-0.63	Brown GW					181	182	0.25-0.5	0.33 (0.31)	6.3 (5.7)
CG38	17/10/2000	0.49	0-0.49	Grey GW		434352.027	6495657.656	358.271	178		0-0.25	3.4	8.5
			>0.49	Grey GW (hard)					179		0.25-0.49	6.4	10
	1/11/2000	2.5	0-2.0	Grey GW	>2.5				310		0.5-0.75	3.3	11
			2.0-2.25	Grey/Brown GW					311		0.75-1.0	2.7	6.7
			2.25-2.5	R					312		1.0-1.25	3	7.2
									313		1.25-1.5	6.7	6.7
									314		1.5-1.75	8.7	6.3
									315		1.75-2.0	9.6	6.1
									316		2.0-2.25	7.2	5.8
									317		2.25-2.305	9.8	5.9
									318		2.305-2.36	657	5.8
									319		2.36-2.5	63	4
CG39	17/10/2000	0.69	0-0.2	Brown GP	0	434311.104	6495617.386	355.534	135		0-0.25	0.95	3
			0.2-0.69	Brown GW					136		0.25-0.5	0.41	5.7
CG40	17/10/2000	0.75	0-0.2	Brown GP	0	434296.184	6495663.804	355.878	122		0-0.25	0.41	3.3
			0.2-0.75	Brown GW					123	124	0.25-0.5	0.43 (0.15)	4.9 (5.3)
CG41	17/10/2000	0.82	0-0.2	Brown GP	0	434263.164	6495593.676	353.000	145		0-0.25	0.63	5.2
			0.2-0.82	Brown GW					146	147	0.25-0.5	0.29 (0.17)	4.6 (5.2)

(Source: Thorpe Groundwater and Environmental Services 2001)

Notes:
- Total phenols exceeding 9mg/kg
- L — Lobed, variable penetration of soil by wood tar waste
- R — Massive, hard, indurated laterite caprock
- AMG — Australian Metric Grid
- mbns — Metres below natural surface
- AHD — Australian Height Datum
- mg/kg — Milligrams per kilogram or ppm
- I/S — Insufficient sample for analysis
- * — Samples 164R and 165R are samples 164 and 165 treated with wetting agent

Table 3.3: Soil and Caprock Analytical Results - Speciated Phenols

Test pit ref.	Date sampled	Analysis sample ref.	Sample interval (m)	Phenol (mg/kg)	2-Methylphenol (mg/kg)	4-Methylphenol (mg/kg)	2-Chlorophenol (mg/kg)	2,4-Dimethylphenol (mg/kg)	2,6-Dichlorophenol (mg/kg)	2,4-Dichlorophenol (2,5) (mg/kg)	2-Nitrophenol (mg/kg)	2,4,6-Trichlorophenol (mg/kg)	4-Nitrophenol (mg/kg)	2,4,5-Trichlorophenol (mg/kg)	2436-Tetrachlorophenol (mg/kg)	Pentachlorophenol (mg/kg)
Site A																
AG18	16/10/2000	58	0-0.25	1.6	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		62	0.25-0.5	1.5	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
AG21	16/10/2000	59	0-0.25	1.8	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		60	0.25-0.5	<1.0	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
Site B																
BG19	18/10/2000	183	0-0.25	<1.0	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
	31/10/2000	289	0.5-0.7	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S
		290	0.75-1.0	10	2	7	<0.5	2.8	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
BG25	18/10/2000	203	0-0.25	1.3	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		204	0.25-0.5	1.2	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
Site C																
CG3	17/10/2000	109	0-0.25	<1	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		110	0.25-0.5	1.1	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		112	0.75-0.87	<1.0	<1	<1	<0.1	<1	<0.1	<0.1	<1	<0.1	<1	<0.1	<0.1	<0.1
CG21	17/10/2000	164	0-0.25	1.6	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		164R*	0-0.25	1.9	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		165	0.25-0.37	1.2	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		164R*	0.25-0.37	1.9	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
CG33	17/10/2000	75	0-0.25	1.1	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		76	0.25-0.5	1.5	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
CG35	18/10/2000	174	0-0.25	1.3	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		175	0.25-0.5	1.9	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
	1/11/2000	320	0.5-0.75	1.5	<1	<1	<0.5	1.6	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		324	1.5-1.6	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S
CG38	17/10/2000	178	0-0.25	1.8	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		179	0.25-0.49	1.9	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		314	1.5-1.75	<1.0	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5
		319	2.36-2.5	<1.0	<1	<1	<0.5	<1	<0.5	<0.5	<1	<0.5	<1	<0.5	<0.5	<0.5

Notes: Total phenols exceeding 5mg/kg
mg/kg Milligrams per kilogram or ppm
I/S Insufficient sample for analysis
* Samples 164R and 165R are samples 164 and 165 treated with wetting agent

Table 3.4: Soil and Caprock Analytical Results - Leachability

Test pit ref.	Date sampled	Analysis sample ref.	Sample interval (m)	Leachable Phenol (ug/L)	Leachable o-Cresol (ug/L)	Leachable m and p-Cresol (ug/L)	Leachable 2-Chlorophenol (ug/L)	Leachable 2,4-Dimethylphenol (ug/L)	Leachable 2,6-Dichlorophenol (ug/L)	Leachable 2,4-Dichlorophenol(2,5) (ug/L)	Leachable 2-Nitrophenol (ug/L)	Leachable 2,4,6-Trichlorophenol (ug/L)	Leachable 4-Nitrophenol (ug/L)	Leachable 2,4,5-Trichlorophenol (ug/L)	Leachable 2346-Tetrachlorophenol (ug/L)	Leachable Pentachlorophenol (ug/L)
Site A																
AG18	16/10/2000	58	0-0.25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		62	0.25-0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
AG21	16/10/2000	59	0-0.25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		60	0.25-0.5	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Site B																
BG19	18/10/2000	183	0-0.25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	31/10/2000	289	0.5-0.7	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S
		290	0.75-1.0	820	270	580	<50	190	<50	<50	<50	<50	<50	<50	<50	<50
BG25	18/10/2000	203	0-0.25	1.3	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		204	0.25-0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Site C																
CG3	17/10/2000	109	0-0.25	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		110	0.25-0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		112	0.75-0.87	1.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
CG21	17/10/2000	164	0-0.25	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		164R*	0-0.25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		165	0.25-0.37	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		164R*	0.25-0.37	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
CG33	17/10/2000	75	0-0.25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		76	0.25-0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
CG35	18/10/2000	174	0-0.25	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		175	0.25-0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	1/11/2000	320	0.5-0.75	0.6	0.6	9.6	<0.5	38	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		324	1.5-1.6	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S	I/S
CG38	17/10/2000	178	0-0.25	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		179	0.25-0.49	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		314	1.5-1.75	0.9	<0.5	1.4	<0.5	0.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		319	2.36-2.5	<0.5	<0.5	<0.5	<0.5	<0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Notes: mg/kg Milligrams per kilogram or ppm
I/S Insufficient sample for analysis
* Samples 164R and 165R are samples 164 and 165 treated with wetting agent

4, 6 and 17 caprock samples from Sites A, B and C respectively were submitted for analysis for total phenols. In addition, 1 caprock sample from Site B and 4 caprock samples from Site C were submitted for leaching tests and analysis for individual phenol species as specified in **Section 3.3** (see **Tables 3.2** to **3.4**).

As stated in **Section 3.3,** high concentrations (up to 96 mg/kg) were noted in the caprock. Apart from phenol, the only other species detected were 2-methylphenol, 4-methylphenol and 2,4-dimethylphenol. All these phenols were found in one sample, a caprock sample from location BG19.

Leaching tests showed concentrations of leachable phenols in the caprock were up to 820µg/L. Although leaching tests show a potential for high leachability of phenols from the caprock, the methodology adopted for the analysis does not accurately represent in-situ conditions. The caprock sample is crushed prior to analysis thereby increasing the contact area between the contaminated material and water. In situ, much of the contaminant appears to be inaccessible within small voids in the caprock. The laboratory results therefore probably represent an overestimate of leachability.

3.4 Environmental Fate of Phenols

Monohydric phenols is the general name given to phenol, o-, m-, p- methylphenol (i.e. cresols) and 2,3-, 2,4-, 2,5-, 2,6-, 3,4-, and 3,5- dimethylphenol (or xylenols). These types of phenols all have relatively low vapour pressures and high water solubilities. A list of some of the physical-chemical properties of these phenols is presented in **Table 3.1.**

■ **Table 3.1: Physical-Chemical Properties of some Monohydric Phenols**

Compound	Melting Point (°C)	Boiling Point (°C)	Vapour Pressure (kPa (°C))	Water Solubility (mg/L (°C))	Octanol/Water Partition Coefficient ($\log P_{ow}$)
Phenol	41	182	0.027 (20)	82000	1.46
o-cresol	31	191	0.032 (20)	31000 (40)	
m-cresol	12	202	0.0053 (20)	24000 (20)	
p-cresol	34.8	202	0.0053 (20)	24000 (40)	1.92-1.94
2,3-xylenol	73-75	217			
2,4-xylenol	26	212	0.0083 (20)	170000 (160)	2.5
2,5-xylenol	71-73	212			
2,6-xylenol	44-46	203			2.36
3,4-xylenol	65	225			
3,5-xylenol	68	219			2.35

Most of the information concerning the aquatic environmental dynamics of phenols refers to the compound phenol with little or no information being available for the other monohydric phenols (Verschueren, 1983).

Photo-oxidation, oxidation and microbial degradation are probably the major factors determining the fate of phenols in the environment. The dominance of any one of these removal mechanisms is determined by the conditions prevailing in each specific aqueous system. Sorption plays a minor role in the removal of phenols from the water column (CCME, 1995). The monohydric phenols tend to have a low octanol-water

partition coefficient and are therefore not expected to sorb to organic-rich soils or sediments. The low coefficient also indicates that phenols do not tend to bioaccumulate. Because the compounds are relatively water-soluble and have low vapour pressures, volatilisation isn't expected to be a significant removal process (USEPA, 1979). The major process for removal of phenols from an aqueous system is generally microbial degradation. According to the National Pollutant Inventory (NPI) information sheet on phenol, the compound is slightly persistent in water, with a half-life of between 2-20 days, assuming it is exposed to the elements (the half-life is the amount of time it takes for half the chemical to be degraded). When partitioning in the environment, the fact sheets states that *'about 6.3% of phenol will eventually end up in the air; about 73.3% will end up in the water; and about 0.2% will end up in terrestrial soil and aquatic sediments'*.

Figure 2 shows the potential pathways for contaminants to enter groundwater, and eventually enter waterways. As shown in **Figure 2**, contaminants have the potential to leach from both the soil and the caprock, entering the shallow seasonal aquifer and eventually percolating through the less permeable clay layer and into the deep aquifer. Groundwater from both the shallow seasonal aquifer and the deep aquifer then has the potential to enter waterways downstream.

A site inspection was conducted on 2 March 2001 to locate areas of groundwater seepage, and creeks identified in previous studies. Upon inspection it was noted that groundwater is seeping into a creek approximately 50-100m, in the direction of groundwater flow, from the end of Site C (see **Figure 3**). Changes in the vegetation type were noted in areas of seepage and along the creek line. These features are shown in **Photos 1** to **5**. Given the ephemeral nature of the creek it is unlikely that significant populations of aquatic species, suitable for human consumption, would be present.

The creek is dammed down stream in two places, approximately 150m east of Wallaby Drive (which crosses the creek) and again approximately 250m west of Wallaby Drive (see **Photos 6** and **7**). Anecdotal evidence suggests water collected in the first dam may be used by the nearby volunteer fire fighters and the water collected in the second dam is used for horticulture. Both of these dams were dry upon inspection.

Morangup Brook, referred to in previous studies (Thorpe, July 2000), could not be located during the site inspection. However, no water was noted in drainage lines heading in a northerly direction from Site A toward Morangup Springs.

The unnamed creek behind Site B, referred to in previous studies (Thorpe, July 2000) could not be located during the site inspection.

References

CCME, 1995, Canadian Water Quality Guidelines prepared by the Task Force on Water Quality Guidelines for the Canadian Council of Ministers of the Environment.

National Pollutant Inventory
(http://www.environment.gov.au/epg/npi/contextual_info/context/phenol.html)

USEPA, 1979, Phenol in Water-Related Environmental Fate of 129 Priority Pollutants, Vol II, Office of Water Planning and Standards, US EPA, Washington DC, EPA-440/4-79-029b, pp 83.1-83.11.

Verschueren, K., 1983, Handbook of Environmental Data on Organic Chemicals, 2nd Edition, Van Nostrand Reinhold Co, New York, pp1310.

4. Literature Survey

4.1 Water Quality Guidelines

A survey of readily available water quality guidelines was completed. A list of the references consulted for this survey include:

- Australian Drinking Water Guidelines, NHMRC/ARMCANZ, 1996
- Australian Water Quality Guidelines for Fresh and Marine Waters, 1992
- Draft Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 1999.
- Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment (CCME), 2000
- Canadian Water Quality Guidelines, Canadian Council of Ministers of the Environment (CCME), 1995
- Draft Contaminated Site Assessment Criteria, WA Department of Environmental Protection, 2000
- Dutch Water Supply Decree, RIMH, 1993
- Environmental Quality Objectives in the Netherlands, Risk Assessment and Environmental Quality Division, 1994
- French Decree, Health Ministry, 1989
- German Drinking Water Regulations, Health Centre, 1990
- Guidelines for Assessing Service Station Sites, NSWEPA, 1994
- Japanese Quality Standards of Drinking Water, Ministry of Health and Welfare, 1993
- National Belgium and Regional Guidelines, Department of Health, 1989
- National Institute for Water Supply, Compilation of Odour Threshold Values in Air and Water, Netherlands, 1977
- New Zealand Drinking Water Guidelines, 2000
- South African SABS 241 Specification for Water for Domestic Supplies, Health Department, 1984
- United Kingdom Water Supply Regulations, 1991
- USEPA National Recommended Water Quality Criteria, 1999
- USEPA Region 9 Preliminary Remediation Goals, 2000
- WHO Drinking Water Guidelines, 1993

Table 4.1, Table 4.2 and **Table 4.3** provide a summary of the water quality guidelines for phenols for the identified beneficial uses. The criteria for phenols generally relate to a complex mixture of phenols (excluding chlorinated phenols) and not just phenol. This mixture usually comprises phenol, and ortho-, meta-, para- cresol (methylphenols). No guidelines could be found for phenol or alkylated phenols for water used for irrigation purposes in any of the references reviewed. For use of water for stockwatering, many guidelines indicated that drinking water standards should be adopted.

■ Table 4.1: Drinking Water Guidelines

Parameter	Country/Organisation	Guideline (µg/L)
Phenol		
	National Institute for Water Supply, Netherlands (1977)	1000 (1)
	USEPA (1999)	300 (2)
	USEPA (2000)	22,000
Phenols		
	Australia (1992)	2
	Belgium (1989)	0.5
	Canada (1995)	2
	France (1989)	0.5
	Germany (1990)	0.5
	Japan (1993)	5.0 (3)
	Netherlands (1993)	0.5 (4)
	South Africa (1984)	10 (5) 5 (6)
	United Kingdom (1991)	0.5
Cresols		
o, m cresol	National Institute for Water Supply, Netherlands (1977)	250 (1)
p cresol	National Institute for Water Supply, Netherlands (1977)	55 (1)
Xylenols		
2,4 dimethylphenol	USEPA (1999)	400 (2)
2,4 dimethylphenol	USEPA (2000)	730
2,6 dimethylphenol	USEPA (2000)	22
3,4 dimethylphenol	USEPA (2000)	36

Notes:

(1) Based on odour thresholds in water
(2) Based on organoleptic effects- i.e. taste and odour, which makes water unpalatable but not toxic to humans
(3) Standard based on aesthetic considerations
(4) Value which may be only exceeded in zones specified by the Inspectorate of Health for the Protection of the Environment
(5) Maximum allowable limit
(6) Recommended maximum limit

■ **Table 4.2: Aquatic Ecosystem Protection Guidelines (Freshwater)**

Parameter	Country/Organisation	Guideline (µg/L)
Phenol		
	Australia (1992)	50
	Netherlands (1994)	2 (1)
	WA DEP (2000)	50
Phenols		
(in polluted rivers)	Australia (1992)	0.15-0.02 (2)
	Australia (1999 draft)	6
	Canada (1995)	1 (2)
	Canada (2000)	4
Cresols		
o-cresol	Australia (1992)	0.4 (2)
m-cresol	Australia (1992)	0.2 (2)
p-cresol	Australia (1992)	0.1 (2)
Xylenols		
2,4, dimethylphenol	Australia (1992)	0.4 (2)
2,4-dimethylphenol	Australia (1999 draft)	2.1 (3)

Notes:
(1) Limit value
(2) Guideline for compounds found to cause tainting of fish flesh and other aquatic organisms
(3) Value represents an Environmental Concern Level (ECL)

■ **Table 4.3: Stockwater Guidelines**

Parameter	Country/Organisation	Guideline (µg/L)
Phenols		
	Australia (1992)	2 (1)
	Canada (1995)	2
	WA DEP (2000)	2

Notes:
(1) In Australia, criteria for organic chemicals that should be adopted for stockwatering purposes are the same as that for drinking water. This is to protect the consumers of farm products as some organic compounds can accumulate in animal products.

4.2 Soil Quality Guidelines

One of the USEPA websites consulted as part of the collation of groundwater quality criteria was for USEPA Region 9. This site also provides soil concentrations that are protective of groundwater. These criteria are back calculated from acceptable groundwater concentrations. The term "acceptable groundwater concentrations" was not defined, however it is assumed that this term refers to drinking water guidelines. The acceptable groundwater concentration is multiplied by a dilution factor to obtain a target leachate concentration and a partition equation is then used to calculate the total soil concentration corresponding to this soil leachate concentration. Soil concentrations are provided for phenol and 2,4-dimethylphenol only. These are:

- phenol – 100 mg/kg (DAF 20) and 5 mg/kg (DAF 1)
- 2,4 – dimethylphenol – 9 mg/kg (DAF 20) and 0.4 mg/kg (DAF 1)

A dilution-attenuation factor (DAF) 20 accounts for natural processes that reduce contaminant concentrations over time whereas DAF 1 assumes no dilution or attenuation between the source and the receptor. DAF 1 may be applicable for sites where little or no dilution or attenuation of soil leachate concentrations is expected at a

site, for example, sites with shallow water tables, fractured media, a karst (limestone) topography or source size greater than 30 acres (USEPA 2001). On this basis, adopting the DAF 1 criteria would not be suitable and the DAF 20 criteria should be adopted. Therefore based on the data available in the literature, a remediation goal for soil at the Morangup sites that would be protective of groundwater is 9 mg/kg of 2,4-dimethylphenol. This assumes the following:

- that the contaminant concentrations remaining in the soil reduce over time;
- that the most toxic phenol species in the soil is 2,4 dimethylphenol; and
- that groundwater protection has been taken into consideration. If protection of groundwater was not a consideration, it is likely that the soil criterion for 2,4 dimethylphenol would probably be less conservative (i.e. higher value).

This remediation goal as it applies to the Morangup sites is discussed further in **Section 5.2**.

5. Adopted Criteria

5.1 Groundwater

Based on the literature survey undertaken, the guidelines proposed to protect the beneficial uses of the groundwater are listed in **Table 5.1**.

- **Table 5.1: Adopted Water Quality Criteria**

Beneficial Use	Parameter	Guideline (µg/L)
Drinking Water	Phenols	2
	Cresols	50
	Xylenols	10
Aquatic Ecosystem Protection	Phenols	5
	Cresols	0.1
	Xylenols	2
Stockwatering	Phenols	2

No guidelines were found for use of water for irrigation purposes and it is assumed that water suitable for stockwatering would also be suitable for irrigation of crops.

No criteria were found for any of the ethylmethyl- or trimethylphenols. It is assumed that these have been considered in the derivation of criteria for 'phenols' in general.

Rather than adopting the most stringent guideline for a parameter, the adopted criteria are based on the most recently published Australian guidelines as these are considered to be the most relevant to the local environment and ecosystems.

In terms of protection of aquatic ecosystems, the toxicity of phenolic compounds was found to vary widely, with some species being more sensitive to cresols rather than the xylenols. The guidelines for cresols are, however, based on tainting of fish flesh (i.e. an aesthetic consideration) rather than being levels at which there are toxic effects. Even so, fish in the local creek may be caught and consumed by residents in the area and their appearance should be a consideration. On this basis, the following criteria are proposed for groundwater to ensure protection of all beneficial uses:

- Drinking, stockwatering and irrigation – **total phenols not to exceed 2µg/L**
- Aquatic ecosystem protection – **total phenols not to exceed 0.1µg/L**

Analysis of groundwater indicates no phenol contamination to be present in water collected from bores on Site B. Two bores from Site A and three from Site C have been found to contain elevated concentrations of total phenols ranging from 86 to 170 µg/L. These concentrations are significantly greater than the proposed guidelines for protection of the identified beneficial uses, indicating that management measures need to be implemented.

5.2 Soil

5.2.1 Criteria for Phenolic Species

One of the possible remediation measures for the site is to remove the top layer (250mm) of soil from the sites and cap/seal the caprock so that leaching of phenols from this source is minimised. By undertaking this, the only contaminated soil the residents could potentially come into contact with is that between >250 mm and the caprock. Soil in this horizon could be exposed during gardening activities or residents could grow fruit and vegetables in the new topsoil with roots of these plants penetrating into the contaminated soil horizon below. The potential exposure pathways include:

- Soil ingestion, dermal sorption, inhalation of dust during gardening activities or maintenance activities around the house; and
- Ingestion of homegrown produce that has been grown in contaminated soil and has accumulated contaminants.

The only way to determine 'safe' levels of phenols in this soil horizon would be to derive clean-up goals for each contaminant, for each exposure pathway, and chose the most stringent value as a remediation goal. This exercise would probably take considerable effort and additional sampling and analysis given that not all phenolic species in this soil horizon have been characterised. Another option would be to derive criteria for all pathways for the most toxic phenolic species expected to be present and assume that, if the soil is cleaned up to these levels for this species, then protection from other, less toxic, phenol species would be assured.

Advice from Analytical Reference Laboratory (ARL) is that the majority of phenolics present were of a complex nature. Other phenol compounds constituted only very minor portions, mostly below detection limits, of the total phenols. Discussion of whether the risks can be adequately managed using the data available for total phenols and 2,4-dimethylphenols is outlined below.

5.2.2 Criteria for 2,4-Dimethylphenols and Total Phenols

If the USEPA remediation goal of 9mg/kg for 2,4-dimethylphenol is adopted, it assumes no other more toxic phenol species are present. **Table 5.2** presents the concentrations of 2,4-dimethylphenol as a percentage of the total phenol concentration. As shown in **Table 5.2,** on average, the total phenol concentration is made up of 4% 2,4-dimethylphenols. Therefore a sample containing 9mg/kg of total phenols would be expected to contain a concentration of 0.36mg/kg 2,4-dimethylphenols. Given that this is the case, adopting 9mg/kg as criteria for total phenols is similar to adopting the DAF 1 criteria for 2,4-dimethylphenols.

■ **Table 5.2: 2,4-Dimethylphenols as a Percentage of Total Phenols**

Test Pit Reference	Analysis Sample Reference	Total Phenol Concentration (mg/kg)	2,4-Dimethylphenol Concentrations (mg/kg)	2,4-Dimethylphenol as a % of Total Phenols
AG21	59	9.4	<1	5
BG19	290	96	2.8	3
BG25	203	16	<1	3
BG25	204	11	<1	5
CG3	109	12	<1	4
CG21	164	31	<1	2
CG21	164R	31	<1	2
CG35	320	17	1.5	9
CG38	319	53	<1	1
		Average Percentage		4%

Notes:
(1) Only samples showing concentrations of total phenols greater than 9mg/kg are presented
(2) For samples showing concentrations of 2,4-dimethylphenol below detection limits, the concentration has been assumed to be equal to half the detection limit (ie 0.5mg/kg).

In addition, the value of 9mg/kg for total phenols is based on protection of groundwater and, as such, it is expected to be more stringent than remediation goals based on protection from other exposure pathways.

On this basis, a soil criterion of **9mg/kg for total phenols** is proposed to ensure protection of beneficial uses of the groundwater providing it is applied in conjunction with other management measures to control use of the groundwater. Management of contamination in the groundwater is addressed separately.

Note that although the majority of soil results show total phenols to be present at concentrations less than 9 mg/kg, there are some locations where the concentrations are up to 31 mg/kg in the soil and even greater in the caprock. Soil results that exceed the adopted soil criterion of 9mg/kg are highlighted in **Table 3.2**.

6. Remedial Options

6.1 Introduction

As stated in **Section 2.5** the discussion of remedial options which follows, involves the evaluation of the remedial options being considered by the DEP based on the findings of this study. No independent evaluation of other possible options for remediation has been conducted.

Discussion of the remedial options has been documented in this study for completeness.

6.2 Evaluation of Remedial Options

During the course of this study, several potential options for remediation have been discussed. These options included:

- The application of 250mm to the surface of contaminated areas
- The removal of the top 250mm of contaminated material, replacement with clean material, and capping of the caprock.
- Removal of all soil above criteria.
- The remediation of all soil and groundwater.
- Capping of the caprock in conjunction with the methods outlined above.

- **Applying 250mm of material to the surface of contaminated areas**

Monitoring of the groundwater and restrictions on groundwater usage would still be required due to the existing contaminant plume. The application of a layer of material would control erosion of the surface of the contaminated material (and also reduce dust generation), allow growth of shallow rooted plant species and also prevent contact with contaminated soil. This method could also decrease moisture penetration (depending on the choice of material) and hence reduce leaching of contaminants into the groundwater. Potential landuses would still be restricted as contaminated soil would still remain beneath the backfill material and therefore the condition of deep-rooted plant species may be affected.

- **Clean up of the top 250mm of contaminated soil and soil exceeding criteria**

If this option is adopted, monitoring of the groundwater and restrictions on its use would need to be undertaken due to the existing contaminant plume. The removal of the top 250mm of contaminated material and replacement with clean fill would stop surface erosion of the contaminated material (and hence reduce dust generation), allow moisture penetration, reduce dust generation and also prevent human contact with contaminated soil. This would also allow shallow rooted vegetation to be grown on contaminated areas. In addition, leaching of contaminants from the soil to the groundwater would be significantly reduced. However, potential landuses may still be restricted as contaminated soil would still remain beneath the backfill material and therefore the condition of deep-rooted plant species may be affected.

- **Remove all contaminated soil and caprock**

If this option is adopted, monitoring of the groundwater and restrictions on its use would still be needed due to the existing contaminant plume. This option would be

acceptable from health, beneficial use, and ecological perspectives. To assess the practicality of this option would require further work to delineate the nature and extent of contamination contained in the caprock.

- **Clean up all contaminated soil, caprock and groundwater**

This option would ensure the protection of all beneficial uses of soil and groundwater at the site. As stated above, to assess the practicality of remediating all contaminated soil and caprock would require further work to delineate the nature and extent of contamination contained in the caprock. Remediation of the existing groundwater plume also presents technical difficulties.

- **Capping of the caprock**

Capping of the caprock could be used in conjunction with the options outlined above. This would minimise the potential for leaching of contaminants contained in the caprock. If this option is to be undertaken, then further work would be required to delineate the nature and extent of contamination contained within the caprock and to delineate the extent of caprock underlying the sites.

6.3 Preferred Option

The DEP's preferred option involves:

- Excavation of the top 250mm of the soil from visibly contaminated areas
- Excavation of soil deeper than 250mm containing concentrations of contaminants exceeding the recommended criteria
- Backfilling with clean fill
- Delineation and capping/sealing of caprock underlying the site to minimise leaching

Remediation of the existing contaminant plume in groundwater underlying the sites is difficult from a technical perspective. If the preferred remedial option outlined above is undertaken, monitoring of the groundwater and restrictions on its use would need to be undertaken due to the existing contaminant plume.

This study has not independently assessed risks arising from leaching of contaminants contained in the caprock. It is noted that Thorpe (February 2001) indicates:

- "The potential for leaching of phenols to groundwater from the laterite caprock is considered to be minimal.
- It may be feasible to significantly reduce water percolation of phenols through the caprock to the watertable by sealing and grading of the upper surface of the caprock with a cement grate or suitable clay".

The removal of the top 250mm of contaminated material and replacement with clean fill would minimise surface erosion of the contaminated material and also minimise human contact with contaminated soil. This would also allow shallow rooted vegetation to be grown on contaminated areas. Some landuses may still be restricted as contaminated material would remain beneath the backfill material and therefore deep-rooted plant species may be affected.

7. Discussion

Analysis for individual phenol species and the leaching potential of phenols has been limited. Only 26 out of the 335 soil/caprock samples were submitted for analysis of these species and leachability. Analysis of groundwater for these individual phenol species has also been limited. Hence the extent to which the more toxic phenol species are present in soil, caprock, and groundwater at the sites is unknown. The adopted criteria do take into account the presence of a variety of phenol species as they relate to "total phenols" rather than "phenol" alone.

The potential sources of ongoing contamination to groundwater include the soil and the caprock. The potential for contaminants to leach from the caprock is uncertain, however analytical results probably overstate leaching from the caprock in-situ. The methodology used in leach tests conducted on caprock samples does not accurately reflect in situ conditions. Further work would be required to better ascertain the risk posed to groundwater from contaminants contained in the caprock. Due to insufficient information on the nature and extent of contaminants contained in the caprock, this risk assessment does not address risks that exist due to contaminants contained in the caprock.

Even if contaminated soil is removed and contaminated caprock is sealed, management measures for the existing groundwater plume are still necessary. These could include a moratorium on abstraction, monitoring (of the plume movement and contaminant levels), provision of treatment options and provision of alternate sources to existing bore users.

Clean up of the sites to the recommended criteria will not necessarily return beneficial uses to the owners that are equivalent to adjacent uncontaminated lots. For example the remaining contaminants (i.e. those deeper than 250mm) may affect the growth, yield or flavour of produce from deeper rooted crops. Plant uptake trials could be conducted to determine the impact of residual contaminants on plant growth at the sites. A preliminary plant trial protocol is presented in **Appendix C**.

Inspection of the creek west of Site C indicates it is unlikely that significant populations of fish, suitable for human consumption, would be present. However, the criteria of 0.1µg/L, based on protection of aquatic ecosystems (tainting of fish), is recommended as a trigger value for monitoring of groundwater entering the creek, indicating that further investigation is required.

8. Conclusions and Recommendations

Following review of existing literature and taking into consideration the conditions that exist at the Morangup sites, the following criteria are proposed as suitable remediation goals for the sites:

- Soil (protective of groundwater):
  - Total phenols not to exceed 9mg/kg (in conjunction with groundwater management measures).

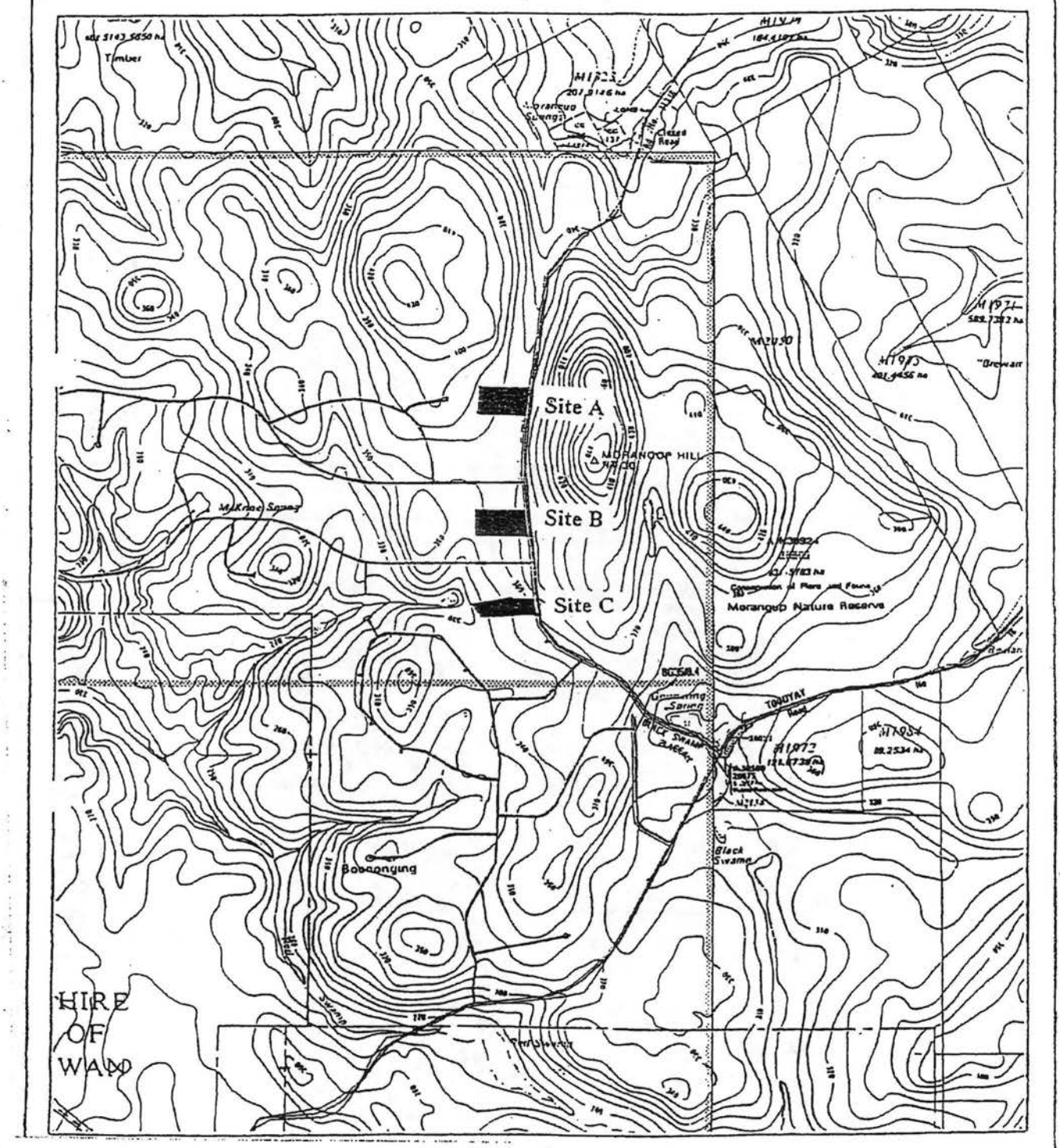
- Groundwater:
  - Drinking, stockwatering and irrigation – total phenols not to exceed 2µg/L
  - Aquatic ecosystem protection – total phenols not to exceed 0.1µg/L

Removal of the contaminant sources does not affect management requirements for the existing groundwater plume. It is recommended that management of groundwater include a moratorium on abstraction, monitoring (of plume movement and contaminant levels) as well as provision of treatment options/alternate sources to existing bore users.

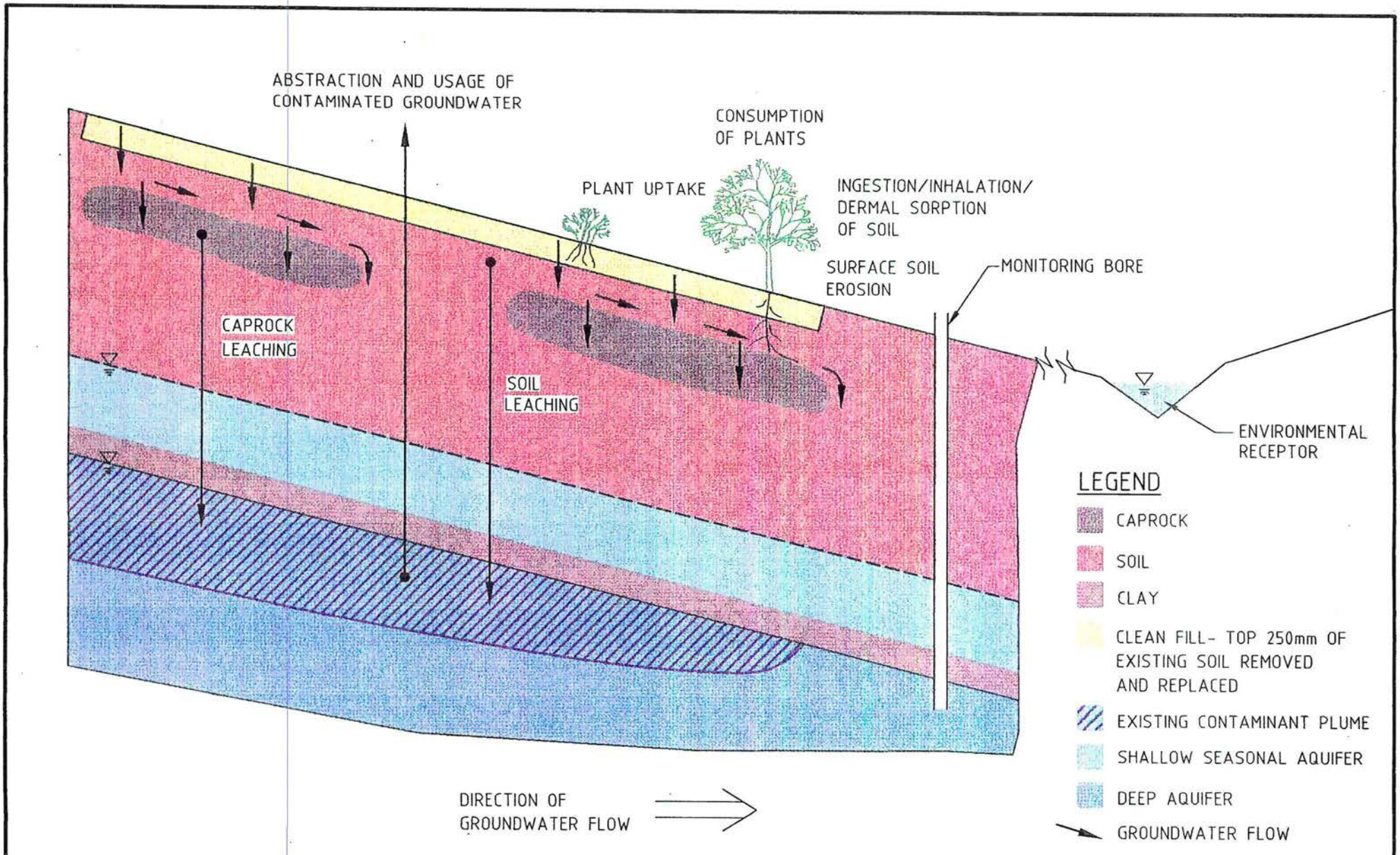
In addition, it is recommended that monitoring of groundwater seepage be conducted at the creek to the west of Site C and a contingency plan be developed in the event that contaminants are found to be entering the creek.

Appendix A Figures

Figure 1
Location of Sites



THORPE
GROUNDWATER & ENVIRONMENTAL SERVICES



SINCLAIR KNIGHT MERZ

MORANGUP ROAD- TOODYAY
POTENTIAL CONTAMINANT PATHWAYS

FIGURE 2
N.T.S.

FIGURE 2 K: \OTHERS\DRWN\04000\Dr04659\Figure2.dwg 02/04/01 10:29:04 MVANNIEL

N
W E
S

Drainage lines (WA)
5 Metre, South West WA

Scale 1:10 000

FIGURE 3

GDA

250 0 250 500 750 Meters

Department of Environmental Protection Western Australia

Appendix B Photographs

Photo 1: Water along the creek line.

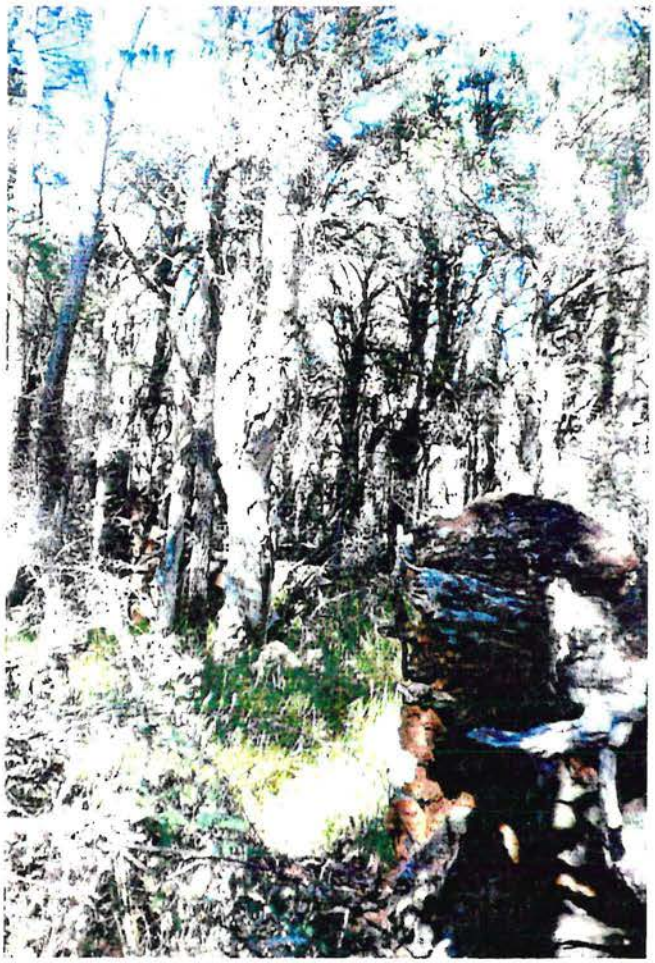


Photo 2: Area of groundwater seepage at the start of the creek. Note the presence of grasses and Paperbarks.

Photo 3: Vegetation adjacent to the creekline

Photo 4: Vegetation away from the creek and seepage areas. Note the absence of grasses and Paperbarks shown in Photos 1 to 3.

Photo 5: Vegetation away from the creek and seepage areas

Photo 6: Dam east of Wallaby Drive

Photo 7: Dam west of Wallaby Drive

Appendix C Preliminary Plant Trial Protocol

Preliminary Plant Trial Protocol

Introduction

The purpose of this preliminary plant trial protocol was to provide the basis for the development of a detailed plant trial protocol.

This methodology could be used to determine the uptake of phenols by plants grown at the site. It is proposed that the plant trials could be undertaken using both uncontaminated 'native' soils spiked with the phenols of concern at appropriate concentrations, as well as replicate trials using contaminated soil from the sites. To assess the effect of irrigation of homegrown produce with contaminated groundwater, some of the plants could be watered with the contaminated groundwater.

This discussion is separate from the risk assessment component of this study, and is included only for completeness.

Procedure

The following general procedure has been developed from a review of relevant literature, addressing techniques for experimental determination of contaminant uptake by plants.

Steps in the procedure are:

1) Determine:
   - Number of compounds to be tested for uptake, n1
   - Number of soil concentrations 'spikes' to be trialled, n2, including zero concentration or control samples
   - Number of replicates, n3
   - Number of plant species or crop varieties tested, n4
   - Number of replicates using field contaminated soil, n5, for positive control replicates

2) Determine size of pots appropriate for the trial based on the type of plant to be trialled, the number of plants to be grown in each pot, and the volume of soil required for each pot, Vp.

3) Calculate total amount of soil material, Vt, needed for tests: $Vt = (n1 \times n2 \times n3 \times n4 + n5) \times Vp$, where $(n1 \times n2 \times n3 \times n4 + n5) = Nt$ which is the total number of pots.

4) Collect enough uncontaminated soil material to satisfy the total required, including extra to cover loss of soil in experimental mishaps and losses incurred in transport, drying and screening. Spread soil out in a thin layer on a clean floor in a large covered area to air dry. Collect enough field-contaminated soil for positive control replicates and prepare this in a similar manner. If it is decided not to 'spike' the soil, only field-contaminated soil needs to be collected. Soils

which are most likely to be used for growing produce in them should be chosen (this may not necessarily be the top 0.25m if it is going to be removed).

5) After air drying, crush the soil to pass through a 10mm screen, remove stones, gravel and any other coarse materials, as well as vegetable matter lodging on the screen.

6) Mix and homogenise the screened soil thoroughly (a large cement mixer may be suitable). Spread the soil out on the floor again.

7) Take a suitable number of soil samples and analyse in the laboratory for:

   - Concentrations of phenols (need to ensure that control soil to be used for the trials is not already contaminated by phenols)

   - Horticultural parameters relevant to growing plants, including:
     a) soil texture and colour;
     b) pH (1:5 soil to water) and (1:5 soil to dilute $CaCl_2$);
     c) electrical conductivity (total soluble salts);
     d) chloride salts;
     e) available phosphorus;
     f) available potassium;
     g) total nitrogen by Kjeldahl (TKN);
     h) total organic carbon (TOC);
     i) aggregate slaking and dispersion;
     j) moisture content at air dry stage (26°C) and Field Capacity.

   - Soil parameters relevant to the soil chemical environment influencing the behaviour (adsorption, desorption, ionic exchange, solubility etc.) of the compounds being studied. These include one or more from the list below:
     a) cation exchange capacity (CEC);
     b) % calcium carbonate (if soil pH > 7.0);
     c) % free iron oxides;
     d) x-ray diffraction to identify clay mineralology;
     e) total organic carbon (TOC) (if not determined as part of the horticultural soil parameters above).

8) Divide soil in n1 equal lots (n1 = number of compounds to be tested).

9) Divide each n lot in n2 portions (n2 = number of different concentrations to be used).

10) If it is decided to 'spike' the soils, apply the phenols in a suitably diluted form (i.e. dissolved in a suitable solvent) to each portion of soil and mix thoroughly (in a cement mixer). If a solvent is used, allow the soil to dry partially to a moist state so that it no longer behaves like a slurry and can be easily handled. Take composite soil samples to check on uniformity of concentration of phenols in the air-dried soil. This will establish the starting soil concentrations.

11) Select suitable opaque pots to ensure adequate space for plant development, absence of chemical interference from the pot itself and exclusion of light from the soil. Line the pots with plastic to prevent loss of water from the base of the pots.

12) Fill the pots in each series of n2 and the number of replicates, n3, with the pre-treated soil and save the rest of the soil in a dark container in a cool place. Repeat this for each phenol compound of n1 compounds to be tested. Leave space for inert mulch on top of the soil to reduce direct evaporation of water from the soil. It may be worth fertilising the pots during the trials. Advice on this, the type fertiliser to use and application rates should be sought from a suitably qualified soil chemist.

13) Moisten all pots to approximate Field Capacity. Weigh all pots and add water to make all the same weight. Water required to achieve Field Capacity = (Field Capacity – moisture content)/100 x dry soil weight.

14) Sow enough seeds per pot to ensure the required number seedlings will remain after thinning any unwanted seedlings.

15) Monitor water availability in pots at least once a day using appropriate equipment such as small tensiometers (measure matrix suction).

16) Water the plants sufficiently to bring soil back to approximate Field Capacity, but make sure no leachate is lost from pots as this may cause losses of phenols from the soil. Keep a logbook of the amount of water added to each pot so that a rough estimate of water use by the plant can be made.

17) To monitor weight loss and therefore watering requirements, pots should be weighed on a daily basis. To compensate for increases in pot weights as a result of plant growth, additional weight should be added to the pot starting weight at weekly intervals. The adjustments to weight additions could be determined during preliminary growing trials or made based on a comparison with the size of plants grown in control pots.

18) To evaluate effect of time and/or cumulative transpiration by the plant of phenols from the soil, set up a parallel trial in which potted plants are harvested much later (e.g. at a time when they have reached full maturity). This parallel trial can take the form of one extra replicate of a few selected soil treatments.

19) To assess the impact of irrigation using contaminated groundwater on plant growth and the uptake of this water, control samples will be used which are to be watered with contaminated groundwater only. Control samples may include plants grown in clean soil and plants grown in contaminated soil as well.

20) At harvest time, collect all plant material, remove adhering soil, divide and separate those parts that will be analysed separately (i.e. leaves from roots), place in labelled paper bags and air dry at 26°C. Have all plant parts and soils analysed for residual compounds. Make sure can distinguish between plants that have been

watered with clean water and those which have been watered with contaminated groundwater.

21) Growth observations which should be noted on a daily basis include germination rates and percentage germination (based on number of seeds planted), leaf discolouration, spotting or curling, and variation in plant sizes depending on the contaminant.

Considerations for this Plant Trial

In order to determine the soil concentrations to be used as part of a potential plant trial to determine the uptake of phenols, it is important that the following be considered:

- the expected concentrations in plant material at the soil concentrations of concern; and
- the analytical detection limits for the determination of phenols in plant material.

A conservative estimate of the ratio between the phenol concentrations in soil and that in the plant material has been made based on documented procedures and the Dutch HESP model. It is possible that such estimates overestimate the actual uptake and accumulation of contaminants in plant material (due to degradation, metabolism, and limited translocation of contaminants). However, the estimates have been used as the basis for determining the concentrations of contaminants in soil to be used as part of a trial. As it is difficult to find the physical-chemical data needed for input into the model for the methoxy phenols (and other similar exotic species found in the soil), calculations have been undertaken for phenol and methyl-phenols (cresols) only. As these compounds are more water-soluble than the corresponding methoxy compounds, the calculated uptake into the plants is expected to be greater than that expected for the less soluble species present in the soil.

It is important that the concentrations of phenols in soil used as part of the trials reasonably reflect the soil concentrations that are likely to be of concern at the site. Based on estimated plant uptake and exposure parameters for residents at the site, preliminary soil acceptance criteria have been determined. Such criteria have only been developed for the purpose of identifying the contaminant concentrations in soil that would be of concern with respect to agricultural use of the site. The preliminary soil acceptance criteria are presented in **Table C.1**.

Table C.1: Summary of Acceptable Soil Criteria

Contaminant	Target Produce Concentration (mg/kg) [4]	Root Conc/Soil Concentration [1]	Stem Conc/Soil Concentration [1]	Soil Conc/Produce Concentration [2]	Target Soil Concentration (mg/kg) [3]
Phenol	25.5	1.5	1.3	0.71	18.1
o-cresol	4.25	0.43	0.24	2.99	12.7
m-cresol	4.25	1.3	0.72	0.99	4.2
p-cresol	4.25	0.9	0.51	1.42	6.0

Notes:

(1) Determined using HESP (Dutch) model

(2) Soil conc/prod conc = 1[(root/soil + stem/soil)/2]

(3) Target soil conc = soil conc/prod conc x target produce conc

(4) The Target Produce Conc was calculated assuming the following:

- amount of produce ingested = 0.54 kg/d adult and 0.27 kg/d for child.
- 30% of total produce consumed comes from contaminated source.
- exposure is for 350d/yr.
- children exposed for 6 years and adults for 24 years.

The predicted concentrations of phenols that are acceptable in produce have been calculated based on toxic effects. There are likely to be little data on the concentration of phenol in produce which will be unacceptable due to aesthetic considerations such as odour and taste. These concentrations could well be much lower than those predicted based on toxic effects. Further investigation of this could be assessed through the establishment of odour and taste panels or a study of maximum residue limits in foodstuffs (ie. market basket surveys etc.).

It may be worth considering whether plants will even grow in soil from the site prior to embarking on the plant trial proper. A preliminary growing trial could be established to observe seed germination rates and plant growth (ie. growth of radish and lettuce) in uncontaminated soil from the site and to compare the performance of different lettuce and radish varieties with the view of selecting preferred plant varieties for the uptake trial. If 'spiking' of soils with phenols in solvent is considered to be an option for the trials, the pre-trials could have pots which have had solvent added to the soil to assess the effect of this too. **Table C.2** outlines what a sample pre-trial set up may include:

- **Table C.2: Sample Pre-Trial Set-Up**

Pot number	Radish/Lettuce Variety	Soil
1	Salad crunch	Clean
2	Scarlet globe	Clean
3	Salad crunch	Solvent added
4	Scarlet globe	Solvent added
5	Etc	etc

If a pre-trial is considered worthwhile, the pots, mulch and watering regime proposed for the trial proper should be used.

APPENDIX THREE
Water and Rivers Commission Approval of Risk Assessment

WATER AND RIVERS
COMMISSION

YOUR REF
OUR REF 14181
ENQUIRIES P I Manning
DIRECT TEL 9278 0443

Ms Catherine Bozanich
Project Manager
Waste Management Division
Department of Environmental Protection
Westralia Square
141 St Georges Terrace
PERTH 6000

Dear Catherine

MORANGUP RISK ASSESSMENT REPORT

I refer to your recent discussions with Mr P I Manning of the Commission, regarding the report provided by Sinclair Knight and Merz (SKM).

Please be advised that we have no objections to the proposed strategy as put forward by SKM.

Yours sincerely

John Ruprecht
MANAGER
LANDUSE IMPACT BRANCH

25 June 2001

WASTE MANAGEMENT DIVISION - DEP			
DATE 29/07/01	REC'D		CRN No. 17100b
DIST CBo.	ACTION	INITIAL	DDATE 29/7/01
FILE No.			ENTERED

HYATT CENTRE 3 PLAIN STREET EAST PERTH WA 6004
PO BOX 6740 HAY STREET EAST PERTH WA 6892 TEL (08) 9278 0300 FAX (08) 9278 0301
EMAIL ADDRESS correspondence@wrc.wa.gov.au
NATIONAL RELAY SERVICE (AUSTRALIAN COMMUNICATION EXCHANGE) 132 544
MANAGING AND PROTECTING WESTERN AUSTRALIA'S MOST VITAL RESOURCE

APPENDIX FOUR
Health Department Approval of Risk Assessment

HEALTH DEPARTMENT OF WESTERN AUSTRALIA

00-06181
S Taylor 9388 4957

DEPARTMENT OF
ENVIRONMENTAL PROTECTION
RECORDS SECTION

10 MAY 2001

FILE NO
NAME
FILE NO
NAME

Ms Catherine Bozanich
Project Manager
Waste Management Division
PO Box K822
PERTH WA 6842

Dear Catherine

Thank you for the Draft 'Risk Assessment of Contaminated Sites near Morangup Road, Toodyay' produced for the Department of Environmental Protection (DEP) by Sinclair Knight Mertz. The document was received by the Health Department of Western Australia (HDWA) on 7 May 2001 and has now been assessed by Officers in the Toxicology Section.

The methodology adopted is consistent with current Australian risk assessment practices as outlined in the *National Environmental Protection (Contaminated Sites) Measure*, 1999. Based on available literature the remediation goals recommended in the report are protective of human health for the identified proposed and future realistic uses of the site. It is important to note that our assessment is limited to human health risk. It is not the responsibility of the HDWA to comment on the protection of the environment.

The report did raise the following points that will need to be clarified before remediation commences.

1. The remediation strategy for the contaminated caprock – different methods are outlined but the criteria for deciding remediation strategy is not.
2. The ongoing management of the groundwater contamination plume. There is a need to identify the responsibility for management and the development plan.

The preferred DEP option for remediation of excavating the top 250mm of contaminated soil is supported by the HDWA. As mentioned in the report this will minimise human contact with the soil, and allow shallow rooted vegetation to grow.

Grace Vaughan House 227 Stubbs Terrace Shenton Park 6008 Tel (08) 9388 4999 Fax (08) 9388 4955
Letters PO Box 8172 Perth Business Centre Western Australia 6849
http://www.health.wa.gov.au

The vegetation will help to suppress dust from the site by decreasing surface erosion. The dust was identified as the major vehicle of exposure to the receptors at the site by a human health risk assessment carried out by the HDWA.

I trust these comments are useful.

Yours sincerely

Peter Di Marco PhD
PRINCIPAL TOXICOLOGIST

9 May 2001
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APPENDIX FIVE
Health Department Assessment of Groundwater Contamination

Department of Environmental Protection

RECEIVED
24 JUL 2000
TOXICOLOGY

Head Office:
Westralia Square
141 St Georges Terrace
Perth, Western Australia 6000
Tel (08) 9222 7000 Fax (08) 9322 1598
http://www.environ.wa.gov.au

Postal Address:
PO Box K822
Perth, Western Australia 6842

Dr Peter DiMarco
Environmental Health Services
HDWA
Grace Vaugam House 227 Stubbs Terrace
SHENTON PARK WA 6008

Our Ref 11/90/156 v5
Enquiries Sally Narvaez

Dear Dr DiMarco

INVESTIGATION OF GROUNDWATER CONTAMINATION AT MORANGUP ROAD, TOODYAY

Please find attached a copy of the report entitled "Investigation of Groundwater Contamination at Morangup Road, Toodyay" authored by Thorpe Groundwater & Environmental Services Pty Ltd. Copies of the report have been distributed to all affected property owners in Morangup, and to state and local government agencies for their information and comment.

This report meets the state government's commitment to investigate the extent of groundwater contamination associated with from the wood-tar waste in Morangup, and completes the first stage of the remediation process.

In response to the conclusions made in section 6 of the report, the Contaminated Sites Branch will conduct additional groundwater sampling to close-out the extent of the groundwater contamination.

I would appreciate any comments you may have in relation to the report to be forwarded to the Contaminated Sites Branch, of the Department of Environmental Protection at your earliest convenience. Alternatively, please contact Sally Narvaez on 9222 7118 to discuss any issues or concerns.

Yours sincerely

ENVIRONMENTAL HEALTH SERVICE
24 JUL 2000
CORPORATE DOCUMENTS

for Fred Tromp
DIRECTOR
POLLUTION PREVENTION DIVISION

21 July 2000

Enc

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CUSTOMER FOCUS
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24/7

Western Australia
Health Department of Western Australia
Environmental Health Service

Your ref:
Our ref: 11/90/156 v5
Enquiries: 00-06533
P Di Marco

DEPARTMENT OF
ENVIRONMENTAL PROTECTION
RECORDS SECTION
- 4 AUG 2000
FILE No 11/90/156
NAME Sally Narvaez
FILE No
NAME

Mr Fred Tromp
Director
Pollution Prevention Division
Department of Environmental Protection
PO Box K822
PERTH WA 6842

Attention: Ms Sally Narvaez

Dear Mr Tromp

INVESTIGATION OF GROUNDWATER CONTAMINATION AT MORANGUP ROAD, TOODYAY

Thank you for your letter of 21 July 2000 requesting comments on the report entitled *"Investigation of Groundwater Contamination at Morangup Road, Toodyay"* by Thorpe Groundwater & Environment Services Pty Ltd.

We have reviewed the document and the reviewer's comments are attached.

Thank you for the opportunity to comment on this issue.

Should you have any queries, please do not hesitate to contact me on 9388 4997.

Yours sincerely

Peter N Di Marco PhD
PRINCIPAL TOXICOLOGIST

2 August 2000

Attach.

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157625

File Number: 00-06533

INVESTIGATION OF GROUNDWATER CONTAMINATION AT MORANGUP ROAD, TOODYAY

Introduction

The Toxicology Section of Environmental Health has received a report entitled *Investigation of Groundwater Contamination at Morangup Road, Toodyay, Western Australia* by Thorpe Groundwater and Environmental Services dated 18 July 2000.

The report comprises results of soil and groundwater samples taken from three properties in Gidgegannup:

Site A: Lot 3 Morangup Road
Site B: Lot 81 Morangup Road
Site C: Lot 11 Morangup Road

Background

Soil samples were taken at 5 locations on each site to provide a composite sample for leachate testing for total cresols. Samples were also tested for total phenols, TPH and PAH. Groundwater samples were taken from 13 locations: 2 bores on Site A, 2 bores on Site B and 9 bores on Site C. The samples were tested for total phenols, TPH and PAH. Additionally, water from an existing contaminated bore (CD1) was tested for the same contaminants.

Sites A, B and C contain 11,100 m^3 of wood-tar contaminated material extending on average to 0.35 m depth. The wood-tar wastes in the soil contain levels of phenols, TPH and PAH which are well below health investigational guidelines. As such the waste material does not pose a health risk to the occupants of the properties. The material however, has water repellent properties that might impact on environmental targets.

Contaminants were detected in a number of test bores as follows:

	Concentration (µg/L)									
	A1MB	A2MB	B1MB	CD1	C1MB	C2MB	C4MB	C9MB	C10MB	PRG*
Total Phenols	86	89		170	95		90			22000
TPH				270						
PAH	1.28	2.02		2.65			0.78	0.07	0.1	
Acenaphthylene	0.73	0.42		1.2	0.1		0.57			
Acenaphthene				0.02						370
Fluorene		0.34	0.02	0.21						240
Fluoranthene				0.05						1500
Naphthalene	0.39	0.88	0.03	1.0	0.05	0.01	0.21	0.07	0.08	620
2-Methyl-naphthalene	0.09	0.33	0.02	0.17					0.02	
Phenanthrene	0.07	0.05								

*: US EPA Provisional Remediation Goal (PRG)

Total phenols were detected at 86 - 95 µg/L, except for the pre-existing contaminated bore (CDI) at which the concentration was 170 µg/L.

There is no Australian drinking water guideline value for total phenols. However, the US EPA has set a Provisional Remediation Goal (PRG) of 22000 µg/L for phenol itself. Australian drinking water guidelines list guideline values for three specific phenols: 2-chlorophenol (300 µg/L), 2,4-dichlorophenol (200 µg/L) and 2,4,6-trichlorophenol (20 µg/L). The values reported for the groundwater are within the guideline values for 2-chlorophenol and 2,4-dichlorophenol (200 µg/L), but higher than the guideline value for 2,4,6-trichlorophenol. Since only total phenols have been measured, it is not possible to say which phenol is contributing to the total value. However, it is reasonable to conclude that the water levels of phenols reported do not pose a risk to health. Moreover, all values reported are at least 40 times higher than the aesthetic guideline values for the three phenols (0.1 - 2 µg/L). Hence the taste of the water might make it unsuitable for drinking.

Total PAH concentrations range from < 0.01 µg/L to 2.65 µg/L with benzo(a)pyrene undetectable at 0.01 µg/L, both the guideline value and the limit of determination. There is no drinking water guideline set by the NHMRC for total PAH. The values reported for some individual PAHs are below PRG values set by the US EPA. Consequently it may be concluded that PAH contamination of the groundwater dose pose a health risk.

TPH were below the limit of determination for all bores tested, except the existing contaminated bore CD1. Chromium levels were well within guideline values.

Conclusions

Disposal of wood-tar waste on properties along Morangup Road Toodyay has resulted in soil and water contamination on the properties. The results presented in this report suggest that the contamination does not pose a health risk to people living on the properties or drinking the water. However, the water might be unpalatable because of the phenol content. Removal or isolation of the contaminated soil is indicated to prevent additional leaching to groundwater.

Disclaimer

This review of the report submitted to HDWA in no way endorses, accepts or approves any of the methods or models used by the authors of the report. The review and opinions given are solely based on the information included in the report submitted for review. The responsibility for the veracity and scientific validity of the analytical results, and the algorithms and outputs of any model used rests entirely with the sponsors and/or authors of the report. Where the report has been identified as lacking or having incomplete information, the examples provided are not exhaustive and it is the author's responsibility to ensure that appropriate information is provided in an acceptable and readily understandable form in all cases.

Reviewer

Peter N Di Marco PhD
PRINCIPAL TOXICOLOGIST
ENVRIRONMENTAL HEALTH

2 August 2000

APPENDIX SIX
Advice that the Contaminated Soil is Suitable for a Class I or II Landfill Facility

M E M O R A N D U M

To: Catherine Bozanich, Acting Manager, Waste Operations Branch.

From: Wayne Ennor (Environmental Officer, Licensing Branch) via Philip Hine (Assistant Director, Pollution Prevention Division). 7/8/01 PTH 7/8/01

Subject: CLASSIFICATION OF SOIL FROM CONTAMINATED SITES NEAR MORANGUP ROAD, TOODYAY

Date: 7 August 2001

The information presented in the documents entitled "Report No. T15, Rep.1, Advice on a Soil Characterisation and Testing Program for Contaminated Sites Near Morangup Road, Toodyay, Western Australia" and the "Department of Environmental Protection, Dust Characterisation and Soil Wetting Program for Contaminated Sites Near Morangup Road, Toodyay Final, February 2001" indicates that the soil is suitable for disposal at a Class I or II licensed landfill.

The in-situ sampling methodology provided in the documents also gives sufficient information to characterise the soil for disposal, therefore, there is no requirement for stockpile sampling to be undertaken. This information is provided as advice only and should not be taken as approval as the final decision to accept the waste is that of the licensed landfill operator.

APPENDIX SEVEN
Health Risk Assessment on Dust

HEALTH DEPARTMENT OF WESTERN AUSTRALIA

Your ref 00-06533
Our ref Sarah Taylor 9388 4957
Enquiries

Mr Shane Sadleir
Department of Environmental Protection
4th Floor Westralia Square
141 St Georges Terrace
PERTH WA 6000

Dear Shane

MORNAGUP- DRAFT REPORT ON DUST CHARACTERISATION

Please find enclosed a review and a health risk assessment of the document entitled "Dust Characterisation and Soil Wetting Program for Contaminated Sites near Morungup Road, Toodyay Final", February 2001 by Sinclair Knight Merz.

The review and opinions provided are based solely on the material provided in the document submitted to the Health Department of Western Australia.

Thank you for the opportunity to review and comment on this document.

Yours sincerely

Peter N Di Marco PhD
PRINCIPAL TOXICOLOGIST

21 March 2001

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SS 23/03/01
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Grace Vaughan House 227 Stubbs Terrace Shenton Park WA 6008 Tel (08) 9388 4999 Fax (08) 9388 4955
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http://www.health.wa.gov.au

CUSTOMER FOCUS WESTERN AUSTRALIA

HEALTH RISK ASSESSMENT
MORANGUP ROAD, TOODYAY

The risk assessment model used is as described in the National Environmental Protection (Assessment of Site Contamination) Measure 1999 and is consistent with the approach taken by Health Authorities in Australia.

EXPOSURE ASSESSMENT

Adults residing along the Morangup road are the receptors considered in this report. This is consistent with what is known about who will be in the area during excavation.

The contaminants of most concern are Phenols and Total Petroleum Hydrocarbons (TPH). Phenol levels do not exceed the HIL (8500 mg/kg) in the dust fraction of the soil or the unfractionated soil. Notwithstanding this aspect a risk assessment on the dust is carried out below. There was also one exceedance of the TPH fraction C_{10}-C_{36} based on the NSW EPA's Guidelines for Assessing Service Station Sites (1994).

EXPOSURE PATHWAYS

The most significant exposure pathway is inhalation of contaminated dust during the remediation, some of which will also be ingested.

Contact with or ingestion of phenols via the groundwater from the domestic bore is not considered here. Conservation of the groundwater for future domestic uses will be the subject of an environmental assessment.

Estimation of amounts of dust contaminants inhaled is based on a number of factors, including respiratory volume, proportion of dust respired, and the concentration of contaminants in the dust (Health Risk Assessment and Management of Contaminated Sites Monograph Series 2 1993). The following are estimates of the exposures to phenols and TPH from dust likely to be generated during the remediation process.

Phenols

Daily Intake (DI mg/kg/day) of phenols from inhaled dust is given by the equation:

$$DI = (C_{di} \times A_{si} \times \text{proportion retained by lungs})/(BW \times 10^6)$$

Where:

- DI = Daily intake of contaminants in the dust (mg/kg/day)
- C_{di} = Concentration of dust in inhaled air ($\mu g/m^3$)
  - = 4.405 mg/m^3 (highest concentration reported under wet conditions)
- A_{si} = Total amount of inhaled dust (mg)
- C_{si} = Concentration of phenols in dust (mg/kg)
  - = 35 mg/kg (highest concentration of phenols reported in dust)
- BW = Body weight
  - = 70 kg
- 10^6 = Conversion factor Kg → mg

Proportion of inhaled dust retained by the lungs = 0.375
Proportion of inhaled dust ingested = 0.375
A_{si} = C_{si} x RV
Where:
RV = Respiratory volume
= 20 m^3/day

Thus DI for phenols = (C_{di} x C_{si} x RV x proportion retained by lungs)/BW
= (4.045 x 35 x 20 x 0.375)/(70 x 10^6)
= 16.5 x 10^{-6} mg/kg/day

A proportion of dust inhaled (0.375) will be trapped by the cilia and mucus of the upper respiratory tract and subsequently ingested.

The DI of phenols from the ingested fraction of dust is given by the equation

DI of phenols = (C_{di} x C_{si} x proportion of inhaled dust ingested)/(BW x 10^6)
= (4.045 x 35 x 20 x 0.375)/(70 x 10^6)
= 16.5 x 10^{-6} mg/kg/day

Therefore the total daily intake of phenols from the dust that may be generated during the remediation is given by the following formula.

Total daily intake (TDI) from dust = DI from inhalation of dust + DI from ingested dust
= (16.5 x 10^{-6})+ (16.5 x 10^{-6})
= 33 x 10^{-6} mg/kg/day
= 0.000033 mg/kg/day

The ADI (Acceptable Daily Intake) set for phenols by WHO (1994) is 0.1 mg/kg/day and the RfD (reference dose) set by the US EPA is 0.6 mg/kg/day. Thus the daily intake of phenols through exposure to dust up to 4.405 mg/m^3 results in an exposure some 3 orders of magnitude (3,000 times) lower than the ADI. Both the ADI and RfD are estimates of a safe level of exposure, including sensitive subgroups, that is likely to be without an appreciable risk of adverse effects during a lifetime.

Monitioring during the trail excavation showed that under dry conditions the dust concentration were some sixty times higher. The daily intake of phenols through inhalation under these conditions would still be some 50 times lower than acceptable levels.

Total Petroleum hydrocarbons

Similarly the exposure to TPH from contaminated dust is estimated as follows.

Daily Intake (DI mg/kg/day) of TPHs from inhaled dust is given by the equation:

DI = (C_{di} x A_{si} x proportion retained by lungs)/(BW x 10^6)

Where:

DI = Daily intake of TPH in the dust (mg/kg/day)
C_{di} = Concentration of dust in inhaled air ($\mu g/m^3$)
= 4.405 mg/m^3 (highest concentration reported under wet conditions)
A_{si} = Total amount of inhaled dust (mg)
C_{si} = Concentration of contaminant in dust (mg/kg)
= 1010 mg/kg (highest concentration of TPH C_{10} –C_{36} reported in dust)
BW = Body weight
= 70 kg
10^6 = Conversion factor Kg → mg
Proportion of inhaled dust retained by the lungs = 0.375
Proportion of inhaled dust ingested = 0.375
A_{si} = C_{si} x RV
Where:
RV= Respiratory volume
= 20 m^3/day

Thus DI for TPH = $(C_{di} \times C_{si} \times RV \times \text{proportion retained by lungs})/(BW \times 10^6)$
= $(4.405 \times 1010 \times 20 \times 0.375)/(70 \times 10^6)$
= 477×10^{-6} mg/kg/day

A proportion of dust inhaled (0.375) will be trapped by the cilia and mucus of the upper respiratory tract and subsequently ingested.

The DI of TPH from the ingested fraction of dust is given by the equation

DI of TPH = $(C_{di} \times C_{si} \times \text{proportion of inhaled dust ingested})/BW$
= $(4.045 \times 1010 \times 20 \times 0.375)/(70 \times 10^6)$
= 477×10^{-6} mg/kg/day

Therefore the total daily intake of TPH from the dust that may be generated during the remediation is given by the following formula.

Total daily intake (TDI) from dust = DI from inhalation of dust + DI from ingested dust
= $(477 \times 10^{-6}) + (477 \times 10^{-6})$
= 954×10^{-6} mg/kg/day
= 0.000954 mg/kg/day

The inhalational RfD set by the US EPA for TPH is 0.2 mg/kg/day and the oral RfD is 0.04 mg/kg/day. Thus the daily intake of TPH through exposure to dust up to 4.405 mg/m^3 results in an exposure at least 80 times (0.000477 mg/kg/day vs 0.04 mg/kg/day for oral intake) lower than acceptable daily intakes.

TOXICOLOGY ASSESSMENT

Poisoning through the inhalation of phenol vapours is recognised by the World Health Organisation International Program on Chemical Safety (WHO IPCS). No cases of death following this exposure scenario have been reported. The major health

symptoms and signs with phenol exposure include, anorexia, weight loss, headache, vertigo, salivation and dark urine.

Accidental high exposure to phenols may cause severe local effects but the available data does not suggest a strong potential for cumulative health effects from chronic exposures.

These effects occur at levels much higher that the acceptable daily intakes set for lifetime exposure and are more likely to occur in an occupational setting with workers handling phenols or phenol containing materials such as wood tar.

RISK CHARACTERISATION

The residents along Morangup Road would be unlikely to suffer adverse health effects from inhalation of the wetted contaminated dust from the remediation procedures recommended in this report.

Alternative approaches to the remediation recommendations made by this report include dust monitoring near the residence houses and the addition of water with a wetting agent a few days before the excavation to minimise dust generation and maximise the moisture content and penetration of the agents into the soil.

There is significant community concern about the risks associated with the dust from remediation that needs to be considered. While the estimated exposures to phenols and TPH in soil and dust are at least 40 times less than health guideline levels of exposure, hence pose no risk to the residents, remediation procedures should aim for suppressing dust as much as possible to avoid adverse health effects caused by the dust itself. High levels of dust may lead to exacerbation of preexisting cardiovascular and respiratory conditions.

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PRINCIPAL TOXICOLOGIST

14 December 2000

File No: 00-06533

DUST CHARACTERISATION AND SOIL WETTING PROGRAM NEAR MORRANGUP ROAD

The Department of Environmental Protection (DEP) submitted the report on dust characterisation and soil wetting program for the contaminated sites Near Morangup Road, Toodyay dated January 2001 to the Health Department of Western Australia (HDWA). The DEP requested that the HDWA review and comment on the veracity of conclusions drawn and to make a preliminary risk assessment.

The document comprises a series of chapters covering introduction and background information, scope of work, methodology, quality assurance procedures, results, discussion, conclusions and recommendations

A summary of, and comments on, each of the sections is provided below. Conclusions of the review are provided in the concluding remarks. The risk assessment is provided in the second section of this report and outlines the risk assessment process, exposure assessment, exposure pathway, toxicology assessment and risk characteristics.

INTRODUCTION AND BACKGROUND

Sinclair Knight and Merz were commissioned by the DEP to undertake dust characterisation and a soil-wetting program at sites near Morangup Road, Toodyay. This was carried out in October 2000. The report was to provide advice on the approach to be taken when remediating the 3 sites.

The history of property contamination stems from when the owner of Lot 3 reported groundwater contamination to authorities in 1992. Contamination with phenolic compounds was discovered when the domestic bore on the property was tested. The source of contamination is most likely from wood-tar wastes. There is anecdotal evidence that wood-tar wastes from Wundowie Charcoal Iron and Steel Industry, Wundowie were dumped on the west side of Morangup Road during state ownership of the plant (Thorpe Groundwater and Environmental Services Pty Ltd). The DEP has made a commitment to the residents that the site will be remediated to a level that the EPA is able to sign off on.

SCOPE OF WORK

This report was aimed to primarily characterise the dust fraction of the soil, the wetting characteristics of the soil and the contaminants in the dust. Characterising the dust fraction of this soil was recognised as being necessary because the level of contamination in the dust may be higher than in the complete gravel soil.

The work involved:

- 10 soil samples, 10 locations in visibly contaminated areas
- screening out 10 fine dust fractions from 10 soil samples

- undertaking chemical analysis of soil and dust samples for
    1. moisture content
    2. total phenols
    3. leachable phenols
    4. PAH
    5. TPH
- Performing soil wetting trial on a 10 m square grid at two locations
- Performing excavation and dust monitoring

Previous preliminary soil sampling and testing had been carried out over the site in August 2000 by Thorpe Groundwater and Environmental services. This preliminary sampling revealed no contamination above Health Investigation Levels (HIL's) but there were exceedances of Ecological Investigation Levels (EIL's).

The guidelines followed in this report were the Contaminated Sites Management series (WA DEP 2000) and the NSW EPA Guidelines for assessing Service Station Sites (NSW EPA 1994) in addition to occupational health and safety criteria for dust inhalation. These guidelines contain both health and environmental investigation levels consistent with the National Environmental Protection (Assessment of Site Contamination) Measure 1999 (NEPM).

WORK AND ANALYSIS

Dust Characterisation

Analytical Reference Laboratory (WA) Pty (ARL) carried out comparison of dust fraction and complete soil. Soil was sieved using a 250 μm sieve to yield a fine dust fraction and gross soil fraction. The fine dust fraction accounted for between 2 and 5% of the complete soil. For the purposes of this review it is assumed that the characteristics of this fine dust fraction are similar to the dust generated during excavation.

The soil and dust fraction was analyised to determine the:

1. Dust fraction
2. Moisture content
3. Total phenols
4. Leachable phenol
5. Speciated PAH
6. Speciated TPH

Soil wetting

Soil wetting was undertaken to determine the degree of dust suppression that could be achieved using water and a wetting agent called 'Penetrator'.

TRIAL EXCAVATION AND DUST MONITORING

Wet and dry plots were excavated to determine the effectiveness of the wetting agents to suppress the dust. A front-end loader was used to excavate and drop material in a manner simulating the loading of a truck. This was carried out at two sites with a wet and dry profile. Dust monitors were located 15 m down wind of the drop point.

RESULTS AND DISCUSSION

Soil and dust results

The soil results showed exceedence of the EIL's for Phenols in all samples but no exceedance of HIL's. The soil was characterised as being suitable for disposal into a class 1 landfill facility.

The dust fraction of the soil showed a higher concentration of all parameters except for leachable phenols and C_6- C_9 TPH.

Soil wetting

The addition of wetting agent to the water was found to increase moisture penetration. Based on these tests it appears that the wetting agent with hoeing between applications will be the best way to suppress the dust and reduce the exposure of the residents to contaminants

Trial excavation and dust monitoring

There was a high background of total suspended particulate (TSP) at the site which was attributed to large vehicles travelling on the unsealed sections along Morangup road.

There were substantial variations in the dust levels between sites, which is most likely due to the different soil types and profiles.

The monitored dust levels decreased when the soils were wetted but the optimum suppression of dust was found to be with the addition of 1% Penetrator in water and hoeing. The total suspended particulates would exceed the ambient criteria if the soil was left dry during excavation.

The report states that there is a potential for accidental excavation of dry material and as the contaminants in the dust have not been analysed it was recommended that the excavation does not occur when the wind blows towards the nearest properties (pg 15).

CONCLUSIONS AND RECOMMENDATIONS

It was concluded from the trial that:

- A 1% concentration wetting agent assisted the penetration of water.

- Even when using the wetting agent water did not penetrate uniformly over the 10 m square plots. Ripping or a similar physical process would be required to enhance the efficiency of the wetting agent.
- Dust emissions from soil with 30% moisture content could be controlled below TSP occupational guidelines with a 50 m buffer zone.
- Some excavation may occur in drier soil or higher wind speeds therefore a dust management plan is required to limit work under these conditions and include other dust control measure.
- There is no health risk assessment undertaken for specific contaminants that may be inhaled with dust.

The report recommends that during excavation of contaminated materials:

- The soil is pre-wetted to suppress dust during ripping.
- Ripping and continuos wetting of the soil to the depth to be excavated.

CONCLUDING COMMENTS

Even though the risk from contaminants is low (see risk assessment) it would be good practice to employ the recommendations of this report to reassure the residents that all is being done to minimise the risks to them from the dust. It is recommended that when the wind is blowing towards the property work should include some dust management practices. If monitoring were to be the method of management adopted, achievable alert and action levels would have to be agreed before work commences. The soil wetting with a wetting agent appears to be an effective method of decreasing the dust at the site during excavation of the contaminated material.

Reviewer

Sarah Taylor
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ENVIRONMENTAL HEALTH

21 March 2001

Department of Environmental Protection

Dust Characterisation and Soil Wetting Program for Contaminated Sites Near Morangup Road, Toodyay

Final

February 2001

SINCLAIR KNIGHT MERZ

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APPENDIX EIGHT
Trial Excavation Report

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1. Introduction

1.1 Introduction

Sinclair Knight Merz was commissioned by the Waste Management Division of the Department of Environmental Protection to undertake a dust characterisation and soil wetting program for contaminated sites near Morangup Road, Toodyay.

1.2 Background

Groundwater contamination was first reported in 1992 by the owner of Lot 3 Morangup Road after a domestic bore on the property was found to be contaminated with phenolic compounds. There is anecdotal evidence that wood tar wastes from the Wundowie Charcoal Iron and Steel Industry were dumped on the western side of Morangup Road during State ownership of the plant (Thorpe Groundwater & Environmental Services Pty Ltd, 2000).

Three principle dump sites have been identified (refer **Figure 1**):

- Site A: Lot 3 Morangup Road, 10.001ha
- Site B: Lot 81 Morangup Road, 10.007ha
- Site C: Lot 11, Morangup Road 9.3885ha

Previous investigations indicate that contaminants of concern are:

- Phenols: Concentrations ranging from 0.43mg/kg to 30mg/kg
- Leachable Total Phenols: Concentrations ranging from <0.05mg/L to 1.8mg/L
- Total Polycyclic Aromatic Hydrocarbons (PAHs): Concentrations ranging from <2.5mg/kg to 3.1mg/kg

The contaminated soil has been observed to be strongly hydrophobic possibly due to wood tar coating the soil particles. Even after considerable rainfall has occurred most of the contaminated soil remains dry.

2. Scope of Work

Sinclair Knight Merz was commissioned by the Department of Environmental Protection to undertake the following scope of work:

- Characterisation the dust fraction of the soil:
  - Collect 10 soil samples from 10 locations within the visibly contaminated areas throughout the contaminated sites as instructed by the DEP representative.
  - Screen out 10 fine dust fractions from the 10 soil samples.
  - Undertake chemical analysis of soil and dust samples for moisture content, total phenols, leachable phenols, PAHs and total petroleum hydrocarbons.
- Perform a soil wetting trial at Sites A and C.
- Perform a trial excavation and dust monitoring at Sites A and C.

3. Methodology

3.1 Dust Characterisation

The objective of the dust characterisation component of the project was to determine the concentration of contaminants in the dust fraction of the soil, and to compare this to the concentration of contaminants in the complete soil sample. The sampling and analysis program was not designed to characterise the nature and extent of contamination on the sites.

The approach to assessing the soil and dust on the site involved three phases:

1) Field investigations involving the manual collection of soil samples.

2) Analytical testing of samples.

3) The review of all results and assessment using recognised criteria.

3.1.1 Soil Sampling

The objective of this sampling and analysis program was to characterise the contaminants contained in the dust fraction of the soil and to provide a comparison between the dust fraction and the complete soil. The sampling and analysis program was not designed to characterise the nature and extent of contamination on the site.

A soil sample was collected from 10 locations within the visibly contaminated areas throughout the contaminated sites. Sampling locations were selected in consultation with a DEP representative. Samples were taken from two locations at Site B, four locations at Sites A and four locations at Site C. Two of the four samples taken at each of Sites A and C were taken in the plots marked for the soil wetting trial (see Section 3.2). Sampling locations are shown on **Figures 2 to 4**.

At each sample location, approximately one to two kilograms of soil was collected from the surface 0 to 0.25m of the soil profile. Samples were collected using a trowel and stored in laboratory supplied plastic soil sample bags.

3.1.2 Analytical Verification

Analysis of soil samples was conducted by Analytical Reference Laboratory (WA) Pty Ltd (henceforth referred to as ARL), located in Wittenoom Street East Perth. Samples were submitted for analysis in accordance with documented chain-of-custody procedures.

A quantity of the soil sample was analysed by the laboratory for the parameters of concern. The remainder of the sample was screened using a 250µm sieve to isolate the fine dust fraction. The fine dust fraction was then analysed for the same parameters.

Soil and dust samples were submitted for analysis for the following parameters:

- Dust Fraction
- Moisture Content
- Total Phenols
- Leachable Phenols (ASLP)

- Speciated Polycyclic Aromatic Hydrocarbons
- Speciated Petroleum Hydrocarbons

3.1.3 Assessment Criteria

The analytical results from soil and dust samples were compared with criteria set out in the Draft Contaminated Sites Management Series (WA DEP 2000), and NSW EPA criteria.

The Contaminated Sites Management Series (WA DEP 2000) sets investigation levels for use to assess contamination levels from both a health and ecological perspective. Analytical results have been compared to both the Ecological Investigation Levels (EIL) and Health Investigation Levels (Setting A) (HIL).

EILs have been used which set contaminant levels to avoid impact or the potential for adverse impact to a sensitive environmental receptor; or to the environmental value or beneficial use of an environmental receptor.

HILs (Setting A) set contaminant levels protective of human health for a standard residential site with garden/accessible soil.

Results are also compared to criteria set out in the Draft Landfill Waste Classification and Waste Definitions (WA DEP 2000). Results are compared to the Contaminant Threshold values (CT), Total Concentration values (CL) and Leachable Concentration values (ASLP) for disposal to a Class 1 landfill facility.

In absence of criteria for TPH in the Contaminated Sites Management Series, results were compared with the NSW Environmental Protection Authority Guidelines for Assessing Service Station Sites (NSW EPA 1994). These guidelines set out threshold concentrations in soils to protect the environment and minimise the risk to public health from the future use of service station sites.

Dust results were also compared to occupational health and safety criteria. These are discussed in Section 5.3.

3.2 Soil Wetting

The objective of the soil wetting trial was to determine the degree of dust suppression achieved through application of a wetting agent to the soil prior to excavation. The soil wetting trial was only conducted at Sites A and C.

Upon consultation with the DEP representative, Reynolds Soil Technologies (Reynolds) was selected as the supplier of an appropriate wetting agent. Soil testing by Reynolds showed that a product called "Penetrator" would be the most effective wetting agent for the site. Approximately a 1% dilution of wetting agent was applied to the "wet" plot at each of the sites.

Two trial sites were marked out as instructed by the DEP representative. Two 10m x 10m areas with similar soil characteristics were chosen, marked out and designated as either "wet" or "dry". The location of these plots are shown in **Figure 2** and **Figure 4**. The diluted wetting agent was applied to the "wet" plot at each site using a hose with a flow-regulated nozzle. The water truck was able to apply 700L of the wetting agent

before needing to refill the tank. Application of each 700L load took approximately 20 minutes, and turnaround time to refill the tank was approximately 40 minutes.

It was estimated that 5000L of water would be required to wet the soil profile of the 10m x 10m area down to 0.5m based on an assumed porosity of 0.1 (ie 10% of the total soil volume is comprised of pore spaces).

The first load of wetting agent was applied to the "wet" plot of Site A and seemed to be effectively soaking into the soil. The next load of water was applied without wetting agent to test whether the presence of wetting agent in the soil profile would allow water to soak into the soil. However significant ponding and runoff of water occurred. The next load, with the addition of wetting agent was then applied to the soil. Upon the completion of this it was noticed that the liquid had only penetrated approximately the top 0.02m of the soil profile. Therefore to reduce runoff and improve penetration of the wetting agent, surface soil was ripped using a backhoe to approximately 0.1m. An additional load of wetting agent was then applied to the plot.

At Site C, the soil was wetted, then ripped using the backhoe prior to application of the next load of wetting agent. After application of the first load of wetting agent it was observed that the liquid had already penetrated deeper than at Site A.

The wetting agent was allowed to soak into the soil overnight, and an additional two loads of wetting agent was applied to the "wet" plot at Site A, and three loads was applied to Site C.

Prior to the trial excavation, on 19 October 2000, an additional load of wetting agent was applied to the "wet" plot at each site to account for overnight evaporation at the surface of the soil profile.

In total it is estimated that the following volumes were applied at each site:

- Site A: 6 loads of wetting agent and 1 load of water 4900L
- Site C: 6 loads of wetting agent 4200L

One surface soil sample was taken from each of the wetted plots after the last load of wetting agent had been applied. These samples were submitted to the laboratory for analysis of moisture content.

3.3 Trial Excavation and Dust Monitoring

Trial excavations of the "wet" and "dry" plots at Sites A and C were conducted to determine the effectiveness of the wetting agent for dust suppression.

A front-end loader was used to excavate materials and drop them from a height onto a stockpile to simulate the loading of trucks. At the "wet" plots, every effort was made to excavate only the wetted portion of the soil profile, however some disturbance of the underlying dry soil did occur.

One load of wetting agent was applied to the area surrounding the "wet" plot to minimise dust created by the loader during the excavation. This would isolate the dust measured by the monitoring equipment to dust created by the dropping of excavated material.

To assess the relative dustiness of the 4 trials, dust measurements were conducted using a total suspended particulate (TSP) high volume air sampler and a DustTrak TSI 8520 continuous dust monitor.

Dust measurements were conducted on the dust generated from drop operation. This operation where the material is dropped onto the tray of trucks from a height of one to two metres is often the largest source of dust during an excavation process. As the operation can be controlled in its location and quantified in the number of drops that take place, this source was used to assess the relative dustiness of the soils.

To measure dust from the front end loader drops, the hi volume air sampler and one DustTrak were placed in a location 15 m downwind of the drop point. The other DustTrak for one trial was held by hand to measure the centre of the cloud. After this operation, because of the very high dust loadings and the yet unknown composition of the dust, the monitor was located at a fixed position around 15 m down wind, but several metres away from the hivol sampler. Therefore measurements of the passing dust plume were obtained at two locations.

For each soil condition, measurements were undertaken over a period of up to 11 minutes during which between five to ten front-end loader drops were made. To assess the background contribution of dust, two one-hour samples were undertaken at the beginning and end of the testing.

Dust concentrations from the high volume air sampler were determined by determining the mass of dust collected by pre and post weighing the filter papers according to AS 2724.3 by ARL and dividing by the volume of air passing through the apparatus.

For the DustTrak a standard inlet was used such that concentrations below 10μm were measured. As concentrations from DustTrak monitors are determined by particle counting and converted to concentrations by using a standard road dust calibration factor the concentrations will only be indicative. That is, concentrations may be up to a factor of two higher or lower. As such the primary purpose is to measure the temporal variation in dust loadings.

In addition to this, a visual record of the trial excavations was taken. Video footage was recorded using a hand held video camera (Video 1) and a stationary video camera mounted on a tripod (Video 2). These videos accompany this report. Note that Video 1 has been attached for completeness but has been provided for the DEP's "information only" as the commentary is of an informal nature.

4. Quality Assurance Procedures

4.1 Field Quality Assurance

Soil samples were collected using a small trowel that was cleaned between sampling locations. Samples were stored in laboratory supplied plastic soil sample bags. The samples were marked with a unique reference number and stored in a chilled container. Samples were submitted to the laboratory using chain of custody documentation (refer **Appendix C**).

4.2 Laboratory Quality Assurance

ARL is a NATA (National Association of Testing Authorities) registered laboratory, registered for specific tests within the field of chemical testing. ARL are NATA registered for the analysis of TPH and PAHs in soil with registration pending for their ASLP preparation and total phenol in water (leachate). They are not NATA registered for total phenols in soil but use fully validated methods for their analysis. ARL were able to meet the required detection limits specified in the tender brief. Quality assurance documentation is presented in **Appendix E**.

4.3 Health and Safety

Site personnel with the potential to be exposed to high levels of dust were supplied with Tyvek barrier suits and a Particulate – Class P1 Dust/Mist Respirator.

5. Results and Discussion

5.1 Dust Characterisation

Field logs from soil sampling are presented in **Table 5.1** below.

Table 5.1: Field Logs

Location	Description	Sample ID	Depth (mm)
1	Pisolitic, clayey, sandy gravel	A1	0 - 200
2	Pisolitic, clayey, sandy gravel	A2	0 - 250
3	Pisolitic, clayey, sandy gravel	A3	0 - 250
4	Pisolitic, clayey, sandy gravel	A4	0 - 250
5	Pisolitic, sandy gravel	C1	0 - 200
6	Pisolitic, sandy gravel	C2	0 - 150
7	Pisolitic, sandy gravel	C3	0- 200
8	Pisolitic, sandy gravel	C4	0 - 200
9	Pisolitic, sandy gravel	B1	0 - 150
10	Pisolitic, sandy gravel	B2	0 - 150

5.1.1 Soil Results

Results of the analysis of soil samples are compared with relevant criteria in **Tables 5.2** to **5.4** below.

All soil samples were found to contain concentrations of total phenols exceeding Ecological Investigation Levels (refer **Table 5.2**).

Table 5.2: Soil Results – TPH, Total Phenols, Moisture Content and Dust Fraction

Results expressed in milligrams per kilogram (mg/kg) unless otherwise stated

Sample ID	Depth (mm)	Total Petroleum Hydrocarbons					Total Phenols in Soil	Moisture Content (%)	Dust Fraction <250µm (%)
		C6-C9	C10-C14	C15-C28	C29-C36	Total C10-C36			
A1	0 – 200	<0.2	<0.2	8.9	4.1	93.1	2.7	1.6	5.2
A2	0 – 250	<0.2	<0.2	20	21	41	3.2	2.6	4.3
A3	0 – 250	<0.2	<0.2	2.9	<0.4	2.9	5.0	1.1	3.5
A4	0 – 250	<0.2	<0.2	<0.2	0.7	0.7	7.0	4.2	5.9
B1	0 – 200	<0.2	<0.2	110	300	410	7.6	1.2	4.7
B2	0 – 150	<0.2	<0.2	170	520	690	7.0	2.7	4.2
C1	0- 200	<0.2	<0.2	170	730	900	8.3	2.9	3.3
C2	0 – 200	<0.2	<0.2	160	460	620	13	2.5	4.3
C3	0 – 150	<0.2	<0.2	70	250	320	2.3	2.4	3.9
C4	0 – 150	<0.2	<0.2	18	11	29	3.5	2.4	3.1
Assessment Criteria									
WA DEP EIL		100	500	1000	-	-	1	-	-
WA DEP HIL – A		-	-	-	-	-	-	-	-
NSW EPA		65	-	-	-	1000	-	-	-
WA DEP CT1		-	-	-	-	-	40	-	-

	Above EIL criteria
XX	Above HIL or NSW EPA criteria
	Above CT1 Criteria

Table 5.3: Soil Results – PAHs

Results expressed in milligrams per kilogram (mg/kg) unless otherwise stated

Parameter	WA DEP EIL	WA DEP HIL - A	A1	A2	A3	A4	B1	B2	C1	C2	C3	C4
Acenaphthylene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Anthracene	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)anthracene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(ghi)perylene	10	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chrysene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(b)fluoranthene	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(k)fluoranthene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(a)pyrene	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dibenz(a,h)anthracene	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Fluorene	-	-	<0.1	0.1	<0.1	0.1	0.1	<0.1	<0.1	1.2	<0.1	<0.1
Fluoranthene	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	<0.1	<0.1
Indeno(1,2,3-c,d)pyrene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	5	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2-mehtyl-naphthalene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phenanthrene	10	-	0.1	0.1	0.1	<0.1	0.5	1.2	1.0	1.2	0.2	0.3
Pyrene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	<0.1	<0.1
Total PAHs	20	20	0.1	0.2	0.1	0.1	0.6	1.4	1.1	2.6	0.2	0.3

	Above EIL criteria
XX	Above HIL criteria

Table 5.4: Soil Results – Total Leachable Phenols (ASLP Test)

Results expressed in milligrams per litre (mg/L) unless otherwise stated

Sample ID	Depth (mm)	Total Leachable Phenols in Soil	Total Phenols in Soil (mg/kg)	Leachable Phenols as a % of Total Phenols
A1	0 – 200	0.38	2.7	14.1
A2	0 – 250	0.51	3.2	15.9
A3	0 – 250	0.45	5.0	9.0
A4	0 – 250	0.3	7.0	4.3
B1	0 – 200	1.1	7.6	14.5
B2	0 – 150	0.35	7.0	5.0
C1	0- 200	0.53	8.3	6.4
C2	0 – 200	1.4	13	10.8
C3	0 – 150	0.15	2.3	6.5
C4	0 – 150	0.45	3.5	12.9
Assessment Criteria				
WA DEP ASLP1		2	-	-
WA DEP CL1		-	42500	-

Above ASLP1 or CL1 criteria

5.1.2 Dust Results

Results from analysis of the dust fraction of the soil are presented in **Tables 5.5** to **5.7** below.

The dust fraction of the soil was defined as the fraction of the soil with a particle size below 250µm. The dust fraction of the soil was found to make up approximately three to five percent of the soil, as shown in **Table 5.2**.

As with the soil samples, the dust fraction of the soil showed concentrations of total phenols exceeding Ecological Investigation Levels. In addition, the dust fraction from location C1 showed concentrations of total petroleum hydrocarbons (C10-C36) exceeding NSW EPA criteria.

The results from analysis of the dust fraction of the soil are compared with the results from analysis of the complete soil sample in **Table 5.8** below. The dust fraction of the soil showed a higher concentration of all parameters analysed for apart from total leachable phenols, which showed lower concentrations than the complete soil sample, and C6-C9, which showed concentrations below detection limits for all soil and dust samples.

Table 5.5: Dust Results - TPH, Total Phenols and Moisture Content

Results expressed in milligrams per kilogram (mg/kg) unless otherwise stated

Sample ID	Depth (mm)	Total Petroleum Hydrocarbons					Total Phenols in Dust	Moisture Content (%)
		C6-C9	C10-C14	C15-C28	C29-C36	Total C10-C36		
A1	0 - 200	<0.2	<0.2	13	2.4	15.4	18	4.9
A2	0 - 250	<0.2	<0.2	86	49	135	16	6.2
A3	0 - 250	<0.2	<0.2	20	4.5	24.5	11	4.2
A4	0 - 250	<0.2	<0.2	24	6.5	30.5	8.8	8.3
B1	0 - 200	<0.2	7.8	300	650	957.8	27	7.6
B2	0 - 150	<0.2	<0.2	280	620	900	35	12.4
C1	0- 200	<0.2	<0.2	210	800	**1010**	29	14.4
C2	0 - 200	<0.2	<0.2	100	210	310	30	8.8
C3	0 - 150	<0.2	<0.2	13	36	49	7.3	11.7
C4	0 - 150	<0.2	<0.2	51	17	68	8.3	11.2
Assessment Criteria								
WA DEP EIL		100	500	1000	-	-	1	-
WA DEP HIL – A		-	-	-	-	-	-	-
NSW EPA		65	-	-	-	1000	-	-
WA DEP CT1		-	-	-	-	-	40	-

	Above EIL criteria
XX	Above HIL or NSW EPA criteria
	Above CT1 Criteria

Table 5.6: Dust Results – PAHs

Results expressed in milligrams per kilogram (mg/kg) unless otherwise stated

Parameter	WA DEP EIL	WA DEP HIL - A	A1	A2	A3	A4	B1	B2	C1	C2	C3	C4
Acenaphthylene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Anthracene	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)anthracene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(ghi)perylene	10	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chrysene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(b)fluoranthene	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(k)fluoranthene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(a)pyrene	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dibenz(a,h)anthracene	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Fluorene	-	-	<0.1	0.2	<0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	0.1
Fluoranthene	10	-	0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1	0.1
Indeno(1,2,3-c,d)pyrene	5	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Naphthalene	5	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2-mehtyl-naphthalene	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phenanthrene	10	-	0.1	0.5	0.2	0.1	0.5	1.3	0.6	0.9	0.7	0.7
Pyrene	-	-	<0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	<0.1	0.1
Total PAHs	20	20	0.2	0.9	0.2	0.2	0.6	1.5	0.6	1.1	0.8	1.0

	Above EIL criteria
XX	Above HIL criteria

Table 5.7: Dust Results – Total Leachable Phenols (ASLP Test)

Results expressed in milligrams per litre (mg/L) unless otherwise stated

Sample ID	Depth (mm)	Total Leachable Phenols in Dust	Total Phenols in Dust (mg/kg)	Leachable Phenols as a % of Total Phenols
A1	0 – 200	0.12	18	0.7
A2	0 – 250	0.07	16	0.4
A3	0 – 250	0.07	11	0.6
A4	0 – 250	0.06	8.8	0.7
B1	0 – 200	0.15	27	0.6
B2	0 – 150	0.06	35	0.2
C1	0- 200	0.11	29	0.4
C2	0 – 200	1.6	30	5.3
C3	0 – 150	0.06	7.3	0.8
C4	0 – 150	0.09	8.3	1.1
Assessment Criteria				
WA DEP ASLP1		2	-	-
WA DEP CL1		-	42500	-

Above ASLP1 or CL1 criteria

Table 5.8: Comparison of Dust and Soil Results

Parameter	Dust Concentration / Soil Concentration[1]										Average
	A1	A2	A3	A4	B1	B2	C1	C2	C3	C4	Ratio
C6-C9	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0
C10-C14	1.00	1.00	1.00	1.00	39.00	1.00	1.00	1.00	1.00	1.00	1.0
C15-C28	1.46	4.30	6.90	120.00	2.73	1.65	1.24	0.63	0.19	2.83	2.4
C29-C36	0.59	2.33	11.25	9.29	2.17	1.19	1.10	0.46	0.14	1.55	3.0
TOTAL C10-C36	0.17	3.29	8.45	43.57	2.34	1.30	1.12	0.50	0.15	2.34	2.2
Total Phenols	6.67	5.00	2.20	1.26	3.55	5.00	3.49	2.31	3.17	2.37	3.5
Moisture Content	3.06	2.38	3.82	1.98	6.33	4.59	4.97	3.52	4.88	4.67	4.0
Total PAH	2.00	4.50	2.00	2.00	1.00	1.07	0.55	0.42	4.00	3.33	2.1
ASLP – Total Phenols	0.32	0.14	0.16	0.20	0.14	0.17	0.21	1.14	0.40	0.20	0.3

Notes:

1 Values below detection limit were assumed to be equal to the detection limit in this calculation

Values are considered to be outliers and therefore were excluded when calculating the average ratio

5.2 Soil Wetting

One soil sample was taken from the surface of each wetted plot after the last load of wetting agent had been applied. Sample A1M was taken from the wetted plot of Site A and sample C1M was taken from the wetted plot of Site C. Results of these analyses are shown in **Table 5.9** below.

Table 5.9: Soil Results – Moisture Content After Wetting

Results expressed as a % unless otherwise stated

Sample ID	Depth (mm)	Moisture Content (%)
A1M	Surface	10.5
C1M	Surface	28.9

Visual observations indicated that the depth of moisture penetration displayed a high degree of spatial variability even with the addition of wetting agent. This was

particularly evident at Site A. From visual observations it is estimated that the wetting agent had only penetrated between 0.05 and 0.1m at Site A and 0.1 and 0.2m at Site C. This variability can be seen in the volume of dust generated from the different loads (see video). Dustiness of the soils at Site A may have been due to the variability of wetting (and therefore the disturbance of underlying dry soil) rather than the lower moisture content.

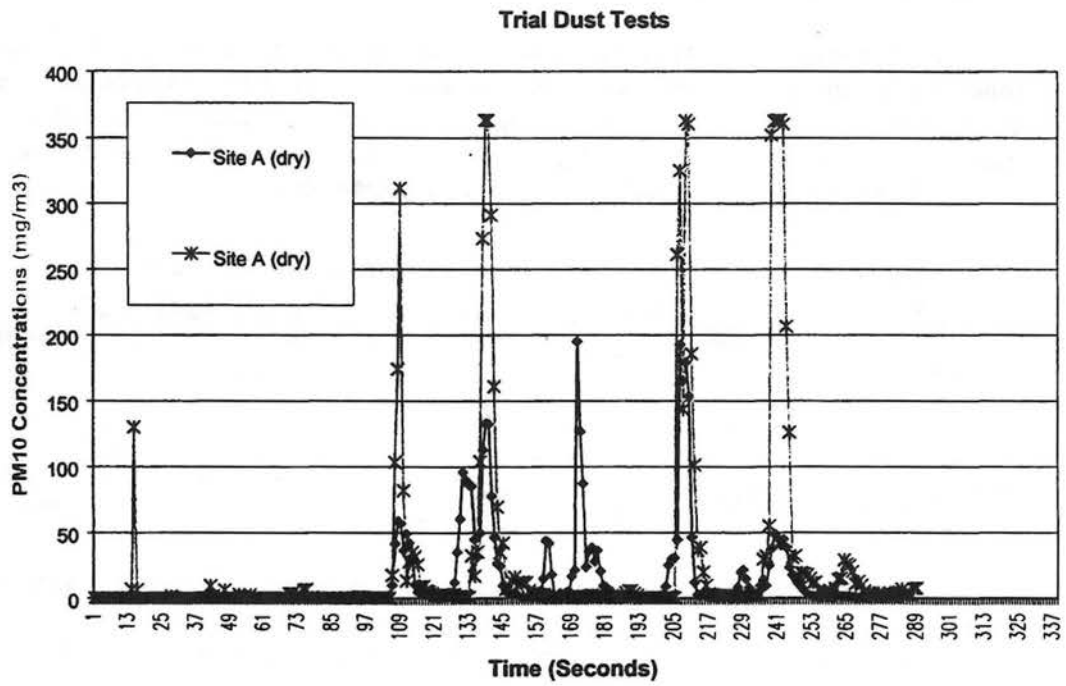
The addition of wetting agent to the water was found to assist in moisture penetration. This was found to occur even when wetting agent had previously been applied to the soil.

5.3 Trial Excavation and Dust Monitoring

Photographs from the trial excavation are presented in **Appendix B.**

Typical dust concentrations measured from the two DustTraks are presented in **Graph 5.1.** This illustrates the discrete clouds of dust associated with the 6 front-end loader drops passing the monitors and also the spatial variability of the plume. For example the last dust cloud passed directly over the second monitor, whilst only touching the first monitor.

- **Graph 5.1 Measured Dust Concentrations from Site A (dry tests)**



Average concentrations throughout the test are presented in **Table 5.10.**

■ **Table 5.10 Average dust concentrations ($\mu g/m^3$) during the tests**

Site	Ground	Averaging Time (min)	HiVol TSP	DustTrak at HiVol	DustTrak #2
Background		71	56	13	not used
A	Dry	3.25	233,090	13,179	26,308
A	wet	11.5	4,405	678	1,554
C	Dry	4	127,950	7,645	4,792
C	Wet	10	1,620	69	93
Background		55	120	12	not used

These indicate:

- Relatively high background total suspended particulate (TSP) concentrations (up to $120\mu g/m^3$. This was due to heavy truck movement on Morangup Road. This road has a single paved centre lane but with fairly heavy truck usage resulted in trucks passing on the shoulders which resulted in occasional plumes of dust.
- Substantial variations between the sites with the highest concentrations from Site A "dry", followed by Site C "dry", with relatively insignificant dust generated from Site C "wet".

These concentrations however are not strictly comparable as:

- A different number of front end loader drops were conducted for each site;
- The length of sampling was different for each test; and
- The number of direct hits on the plume for each sample was different.

As such, to provide a more accurate estimate of the relative "dustiness", the dust mass contribution per direct plume hit was calculated. This mass contribution was determined by estimating the mass loading due to the drops minus the contribution from the background dust and dividing this by the number of dust plumes that directly crossed the sampler. This estimate is presented in **Appendix D**.

■ **Table 5.11 Relative dustiness of wet plots compared to dry plots**

Test	Ratio of Dust Emissions to Dry Tests (Expressed as %)			
	HiVol	DustTrak #1	DustTrak #2	Average
Site A				
Dry	100	100	100	100
Wet	5.5	1.9	2.0	3.1
Site C				
Dry	100	100	100	100
Wet	2.6	0.2	1.0	1.4

As shown in **Table 5.11** there was a general consistency in the relative dustiness calculated using data collected by the different monitors. The data indicate that:

- The trial excavation of the wetted plot of Site A generated on average 3.1% of the dust generated by the excavation of the dry plot.
- The trial excavation of the wetted plot of Site C generated on average 1.4% of the dust generated by the excavation of the dry plot.

5.3.1 Comparison to ambient criteria

Table 5.12 presents dust concentrations measured at the High Volume air sampler compared to occupational and likely ambient criteria. Occupational criteria were obtained from the National Occupational and Health and Safety Commission criteria (NOHSC, 1995). Of the substances measured during the trial they provide occupational levels for Total Suspended Particulate TSP.

Ambient limits were derived from the Kwinana EPP for TSP and from the Draft Determination of Acceptable Air Discharges from Stationary Sources (WA DEP 1996).

■ **Table 5.12 Comparison of Dust Levels to Occupational and Ambient Criteria**

Site	Ground	Averaging Time (min)	TSP ($\mu g/m^3$)
A (A2)	Dry	3.25	233,090
A (A1)	Wet	11.5	4,405
C (C2)	Dry	4	127,950
C (C1)	Wet	10	1,620
Criteria			
Occupation Health[1]		8 hour day	10,000
Ambient Criteria[2]			1000 (15 minute)

Notes
1) Occupational criteria from NOHSC (1995)
2) Ambient criteria obtained from the Kwinana EPP (WA EPA 1992).

The concentrations recorded by the high volume sampler were measured 15 m down wind on the plume centreline. As such, they should be around two to four times higher than concentrations measured at the nearest property boundaries around 50 m away. Therefore, the results in **Table 5.12** indicate that without wetting the TSP concentrations would greatly exceed the ambient criteria that may be applied.

For the wetting tests, the dust concentrations recorded for Site A indicate that levels would be above ambient criteria at the property boundaries and slightly below this criteria for the wetted Site C test.

6. Conclusions and Recommendations

Investigations indicate that contaminants present in the soil are also present in the dust fraction of the soil. The concentration of contaminants in the dust fraction was generally higher than the concentrations in the complete soil sample.

Both soil and dust samples were found to exceed Ecological Investigation Levels for total phenols.

It is concluded from the trials that:

- A 1% concentration wetting agent assisted the penetration of water.
- Even when using the wetting agent water did not penetrate uniformly over the 10m square plots. Ripping or a similar physical process would assist penetration of the wetting agent.
- Where the soil was wetted and disturbance of underlying dry soil was minimised, dust emissions could be controlled below TSP occupational guidelines at a distance of approximately 15m from the excavation.

Given that some excavation may occur in drier soil or at higher wind speeds, excavation should include a dust management plan that will limit work under some weather conditions and include other dust control measures.

Note that no health risk assessment has been undertaken for specific contaminants that may be inhaled with the dust.

It is recommended that the soil be pre-wetted using a wetting agent prior to excavation.

It is recommended that during excavation of contaminated materials:

- **The soil is pre-wetted to suppress dust during ripping**
- **The soil is ripped to the depth to be excavated and continuously wetted during the ripping with sprays above each ripping tyne.**
- **Only the wetted soil should be excavated.**

It is recommended that excavation is limited under certain weather conditions and dust monitoring be carried out at the downwind property boundary during excavation. Achievable alert and action levels would have to be agreed, and a dust control contingency plan be developed before work commences.

It is recommended that health risk assessments should be considered for specific contaminants.

7. References

NOHSC. 1995. *Exposure Standards for Atmospheric Contaminants in the Occupational Environment.* National Occupational Health and Safety Commission.

NSW EPA. 1994. *Guidelines for Assessing Service Station Sites.* Environmental Protection Authority, New South Wales.

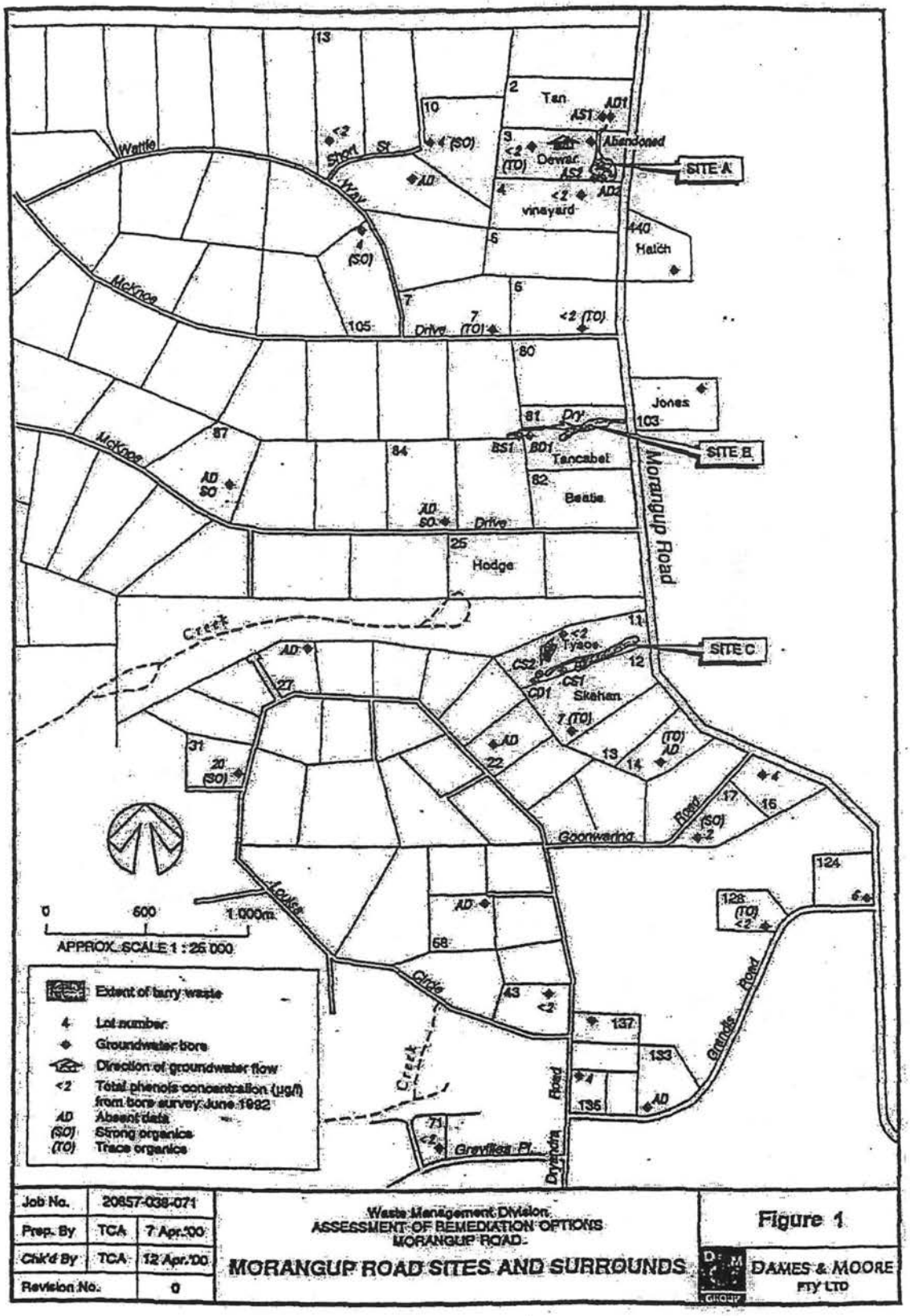
Thorpe Groundwater and Environmental Services Pty Ltd. 2000. *Advice on a Soil Characterisation and Testing Program for Contaminated Sites Near Morangup Road, Toodyay, Western Australia.*

WA DEP. 2000. *Draft Contaminated Sites Management Series.* Department of Environmental Protection, Western Australia.

WA DEP. 2000. *Draft Landfill Waste Classification and Waste Definitions.* Department of Environmental Protection, Western Australia.

WA DEP. 1996. *Draft Determination of Acceptable Air Discharges from Stationary Sources. Department of Environmental Protection*, Western Australia.

Appendix A Figures



Job No.	20857-038-071	
Prep. By	TCA	7 Apr.'00
Chk'd By	TCA	12 Apr.'00
Revision No.		0

Waste Management Division
ASSESSMENT OF REMEDIATION OPTIONS
MORANGUP ROAD

MORANGUP ROAD SITES AND SURROUNDS

Figure 1

DAMES & MOORE PTY LTD

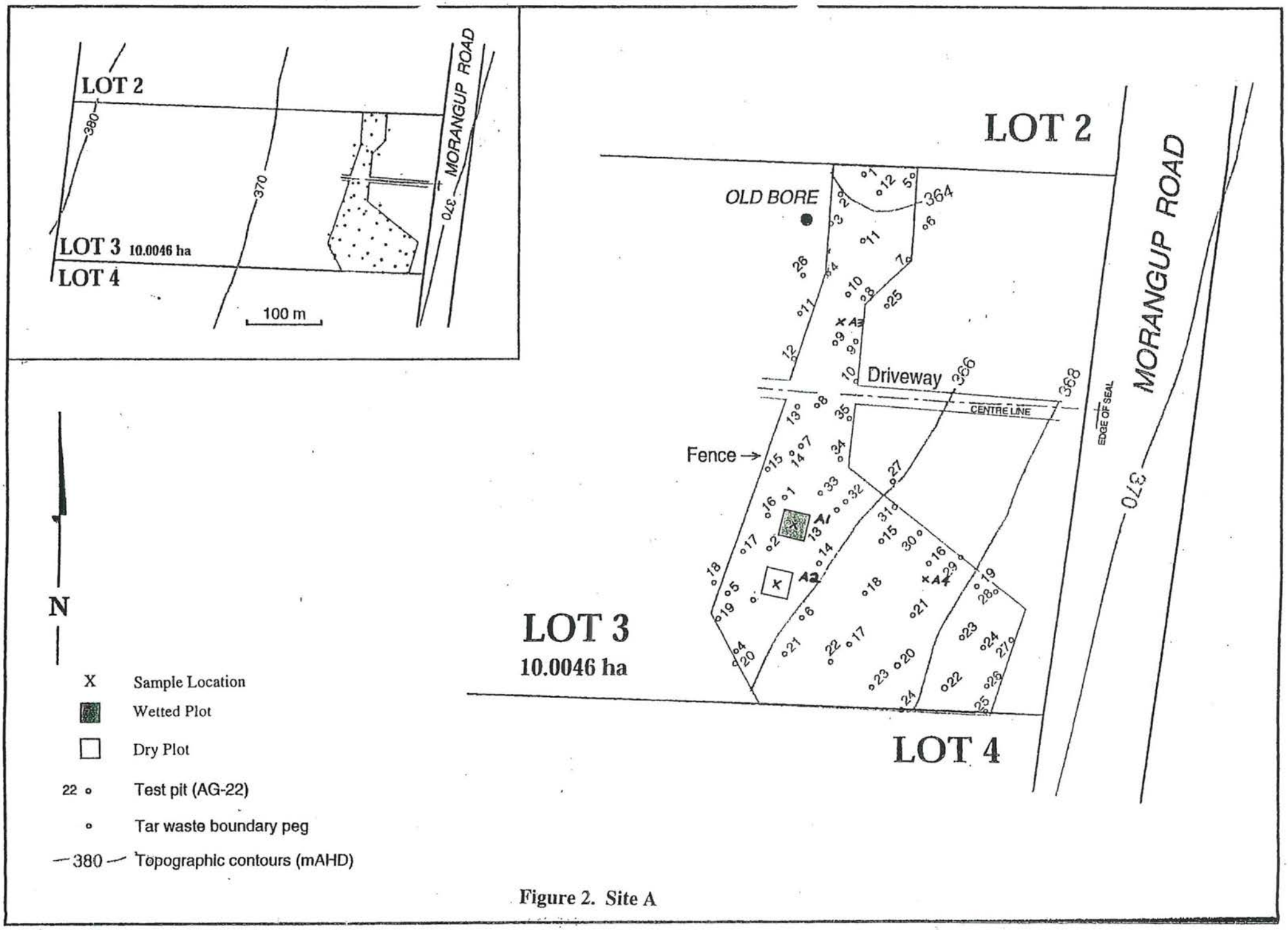


Figure 2. Site A

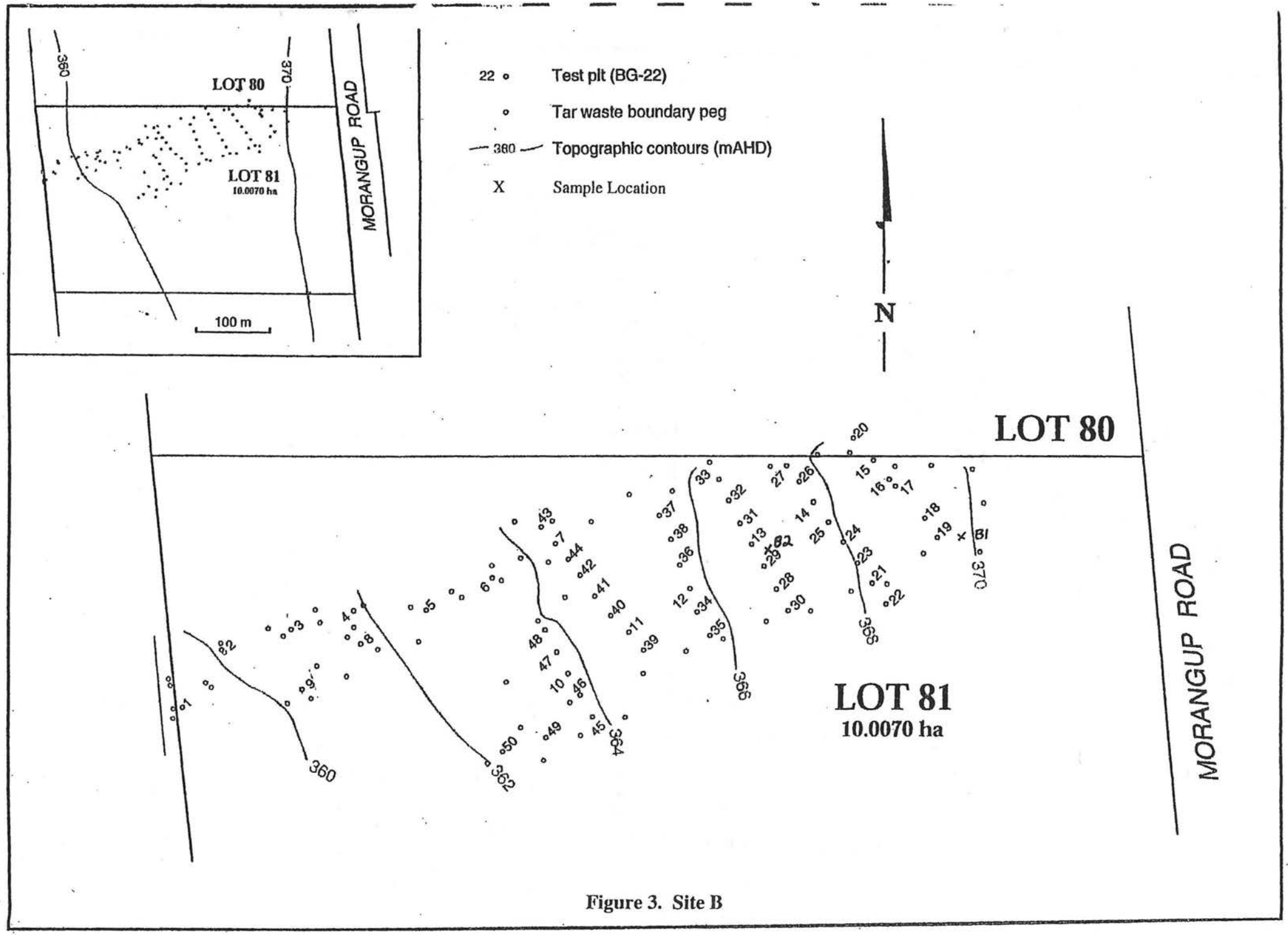


Figure 3. Site B

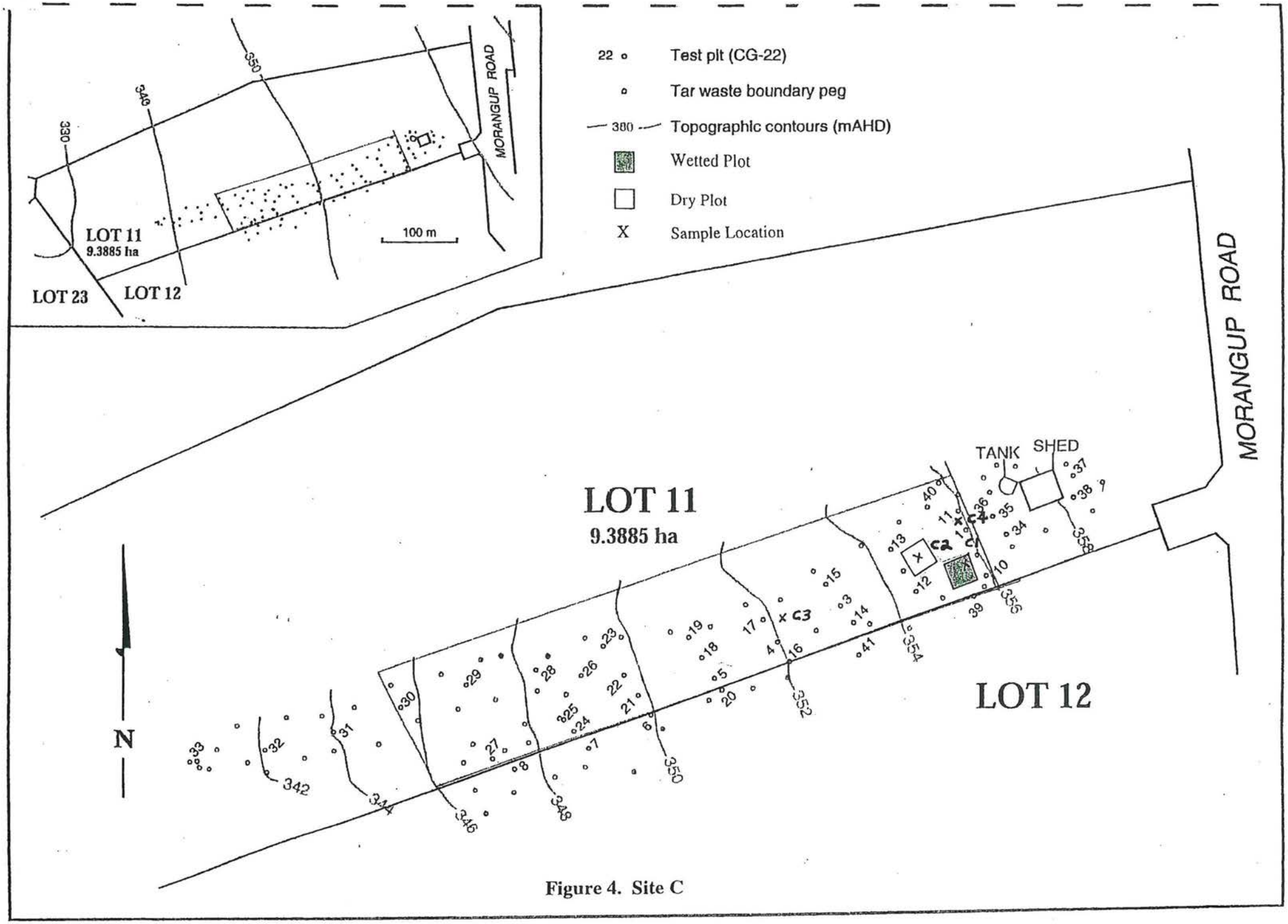


Figure 4. Site C

Appendix B Photographs

Photo 1: Excavation of Site A "wet". Note the dust generated due to disturbance of the dry underlying soil

Photo 2: Trial excavation at Site A "wet".

Photo 3: Trial excavation at Site A "dry".

Photo 4: Trial excavation at Site C "dry".

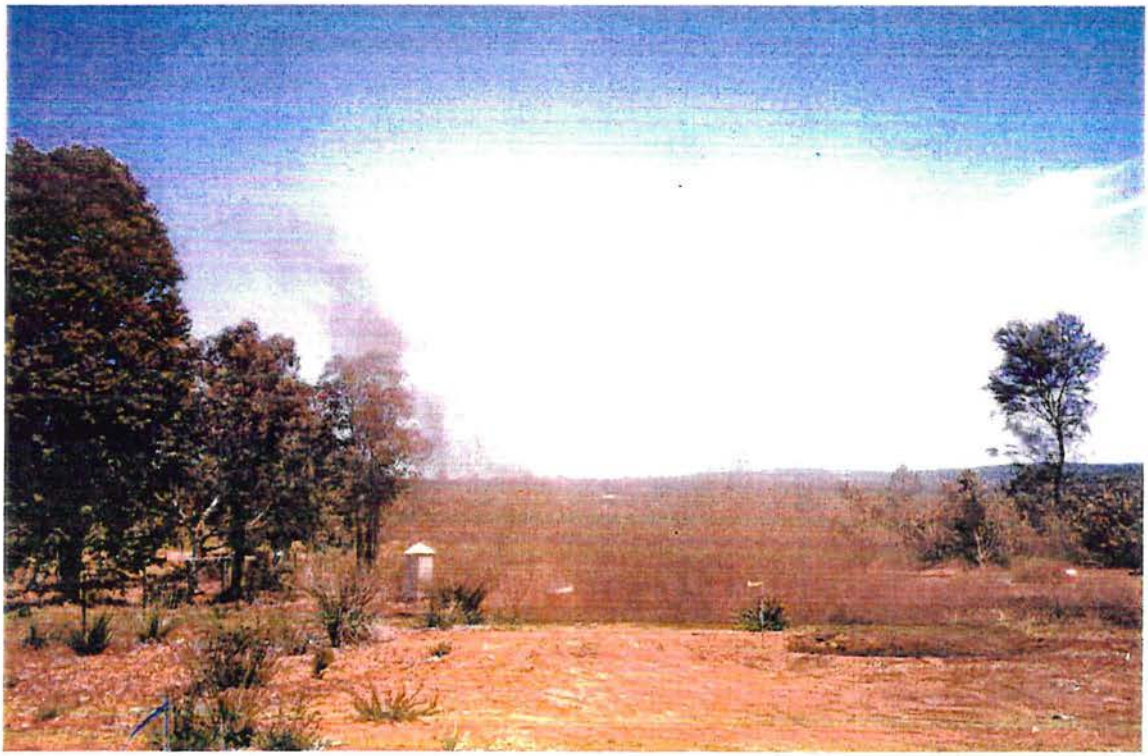


Photo 5: Dust plume generated at Site C "dry".

Photo 6: Trial excavation at Site C "wet". Note the low levels of dust generated.

Appendix C Laboratory Results and Chain of Custody

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.

LABORATORY REPORT

ARL LAB No: 21857-67
DATE: 27 October 2000

CLIENT: Sinclair Knight Merz
263 Adelaide Terrace
PERTH WA 6001

ATTENTION: Mr Ryan Medrana

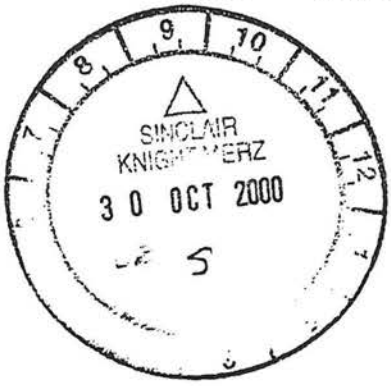
SAMPLE DESCRIPTION: Ten soil samples and ten dust samples as received for analysis of moisture content, total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH) and total phenols.

DATE RECEIVED: 18 October 2000

RESULTS:

DUSTS

Lab No	Sample Mark	C_{6-9}	C_{10-14}	C_{15-28}	C_{29-36}
		mg/kg			
21857	DE01809 A1	<0.2	<0.2	13	2.4
21858	DE01809 A2	<0.2	<0.2	86	49
21859	DE01809 A3	<0.2	<0.2	20	4.4
21860	DE01809 A4	<0.2	<0.2	24	6.5
21861	DE01809 B1	<0.2	7.8	300	650
21862	DE01809 B2	<0.2	<0.2	280	620
21863	DE01809 C1	<0.2	<0.2	210	800
21864	DE01809 C2	<0.2	<0.2	100	210
21865	DE01809 C3	<0.2	<0.2	13	36
21866	DE01809 C4	<0.2	<0.2	51	17



	ACTION	SIGN	DATE
RMI	Sighted		30/10
JOB No.	FILE		

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.
A.C.N. 050 159 898 A.B.N. 91 050 159 898

55 Wittenoom Street, East Perth, Western Australia 6004
Telephone: (08) 9221 1415 Facsimile: (08) 9325 2398
Email: arlwa@wanet.com.au
NATA Registration No. 2377

Mr Ryan Medrana
Sinclair Knight Merz
ARL LAB No: 21857-67
27 October 2000

Lab No	Sample Mark	Total Phenols	Moisture Content
		mg/kg	%
21857	DE01809 A1	18	4.9
21858	DE01809 A2	16	6.2
21859	DE01809 A3	11	4.2
21860	DE01809 A4	8.8	8.3
21861	DE01809 B1	27	7.6
21862	DE01809 B2	35	12.4
21863	DE01809 C1	29	14.4
21864	DE01809 C2	30	8.8
21865	DE01809 C3	7.3	11.7
21866	DE01809 C4	8.3	11.2

Lab No	21857	21858	21859	21860
Sample Mark	DE01809 A1	DE01809 A2	DE01809 A3	DE01809 A4
		mg/kg		
Acenaphthylene	<0.1	<0.1	<0.1	<0.1
Acenaphthene	<0.1	<0.1	<0.1	<0.1
Anthracene	<0.1	<0.1	<0.1	<0.1
Benzo(*a*)anthracene	<0.2	<0.2	<0.2	<0.2
Benzo(*ghi*)perylene	<0.2	<0.2	<0.2	<0.2
Chrysene	<0.2	<0.2	<0.2	<0.2
Benzo(*b*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*k*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*a*)pyrene	<0.2	<0.2	<0.2	<0.2
Dibenz(*a,h*)anthracene	<0.2	<0.2	<0.2	<0.2
Fluorene	<0.1	0.2	<0.1	0.1
Fluoranthene	0.1	0.1	<0.1	<0.1
Indeno(*1,2,3-c,d*)pyrene	<0.2	<0.2	<0.2	<0.2
Naphthalene	<0.1	<0.1	<0.1	<0.1
2-methyl-naphthalene	<0.1	<0.1	<0.1	<0.1
Phenanthrene	0.1	0.5	0.2	0.1
Pyrene	<0.1	0.1	<0.1	<0.1

Mr Ryan Medrana
Sinclair Knight Merz
ARL LAB No: 21857-67
27 October 2000

Lab No	21861	21862	21863	21864
Sample Mark	DE01809 B1	DE01809 B2	DE01809 C1	DE01809 C2
		mg/kg		
Acenaphthylene	<0.1	<0.1	<0.1	<0.1
Acenaphthene	<0.1	<0.1	<0.1	<0.1
Anthracene	<0.1	<0.1	<0.1	<0.1
Benzo(*a*)anthracene	<0.2	<0.2	<0.2	<0.2
Benzo(*ghi*)perylene	<0.2	<0.2	<0.2	<0.2
Chrysene	<0.2	<0.2	<0.2	<0.2
Benzo(*b*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*k*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*a*)pyrene	<0.2	<0.2	<0.2	<0.2
Dibenz(*a,h*)anthracene	<0.2	<0.2	<0.2	<0.2
Fluorene	0.1	<0.1	<0.1	0.1
Fluoranthene	<0.1	0.1	<0.1	<0.1
Indeno(*1,2,3-c,d*)pyrene	<0.2	<0.2	<0.2	<0.2
Naphthalene	<0.1	<0.1	<0.1	<0.1
2-methyl-naphthalene	<0.1	<0.1	<0.1	<0.1
Phenanthrene	0.5	1.3	0.6	0.9
Pyrene	<0.1	0.1	<0.1	0.1

Lab No	21865	21866
Sample Mark	DE01809 C3	DE01809 C4
	mg/kg	
Acenaphthylene	<0.1	<0.1
Acenaphthene	<0.1	<0.1
Anthracene	<0.1	<0.1
Benzo(*a*)anthracene	<0.2	<0.2
Benzo(*ghi*)perylene	<0.2	<0.2
Chrysene	<0.2	<0.2
Benzo(*b*)fluoranthene	<0.2	<0.2
Benzo(*k*)fluoranthene	<0.2	<0.2
Benzo(*a*)pyrene	<0.2	<0.2
Dibenz(*a,h*)anthracene	<0.2	<0.2
Fluorene	<0.1	0.1
Fluoranthene	0.1	0.1
Indeno(*1,2,3-c,d*)pyrene	<0.2	<0.2
Naphthalene	<0.1	<0.1
2-methyl-naphthalene	<0.1	<0.1
Phenanthrene	0.7	0.7
Pyrene	<0.1	0.1

Mr Ryan Medrana
Sinclair Knight Merz
ARL LAB No: 21857-67
27 October 2000

SOILS

Lab No	Sample Mark	C_{6-9}	C_{10-14}	C_{15-28}	C_{29-36}
			mg/kg		
21857	DE01809 A1	<0.2	<0.2	8.9	4.1
21858	DE01809 A2	<0.2	<0.2	20	21
21859	DE01809 A3	<0.2	<0.2	2.9	<0.4
21860	DE01809 A4	<0.2	<0.2	<0.2	0.7
21861	DE01809 B1	<0.2	<0.2	110	300
21862	DE01809 B2	<0.2	<0.2	170	520
21863	DE01809 C1	<0.2	<0.2	170	730
21864	DE01809 C2	<0.2	<0.2	160	460
21865	DE01809 C3	<0.2	<0.2	70	250
21866	DE01809 C4	<0.2	<0.2	18	11

Lab No	Sample Mark	Total Phenols	Moisture Content	Fraction <250µm
		mg/kg	%	%
21857	DE01809 A1	2.7	1.6	5.2
21858	DE01809 A2	3.2	2.6	4.3
21859	DE01809 A3	5.0	1.1	3.5
21860	DE01809 A4	7.0	4.2	5.9
21861	DE01809 B1	7.6	1.2	4.7
21862	DE01809 B2	7.0	2.7	4.2
21863	DE01809 C1	8.3	2.9	3.3
21864	DE01809 C2	13	2.5	4.3
21865	DE01809 C3	2.3	2.4	3.9
21866	DE01809 C4	3.5	2.4	3.1

Mr Ryan Medrana
Sinclair Knight Merz
ARL LAB No: 21857-67
27 October 2000

Lab No	21857	21858	21859	21860
Sample Mark	DE01809 A1	DE01809 A2	DE01809 A3	DE01809 A4
		mg/kg		
Acenaphthylene	<0.1	<0.1	<0.1	<0.1
Acenaphthene	<0.1	<0.1	<0.1	<0.1
Anthracene	<0.1	<0.1	<0.1	<0.1
Benzo(*a*)anthracene	<0.2	<0.2	<0.2	<0.2
Benzo(*ghi*)perylene	<0.2	<0.2	<0.2	<0.2
Chrysene	<0.2	<0.2	<0.2	<0.2
Benzo(*b*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*k*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*a*)pyrene	<0.2	<0.2	<0.2	<0.2
Dibenz(*a,h*)anthracene	<0.2	<0.2	<0.2	<0.2
Fluorene	<0.1	0.1	<0.1	0.1
Fluoranthene	<0.1	<0.1	<0.1	<0.1
Indeno(*1,2,3-c,d*)pyrene	<0.2	<0.2	<0.2	<0.2
Naphthalene	<0.1	<0.1	<0.1	<0.1
2-methyl-naphthalene	<0.1	<0.1	<0.1	<0.1
Phenanthrene	0.1	0.1	0.1	<0.1
Pyrene	<0.1	<0.1	<0.1	<0.1

Lab No	21861	21862	21863	21864
Sample Mark	DE01809 B1	DE01809 B2	DE01809 C1	DE01809 C2
		mg/kg		
Acenaphthylene	<0.1	<0.1	<0.1	<0.1
Acenaphthene	<0.1	<0.1	<0.1	<0.1
Anthracene	<0.1	<0.1	<0.1	<0.1
Benzo(*a*)anthracene	<0.2	<0.2	<0.2	<0.2
Benzo(*ghi*)perylene	<0.2	<0.2	<0.2	<0.2
Chrysene	<0.2	<0.2	<0.2	<0.2
Benzo(*b*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*k*)fluoranthene	<0.2	<0.2	<0.2	<0.2
Benzo(*a*)pyrene	<0.2	<0.2	<0.2	<0.2
Dibenz(*a,h*)anthracene	<0.2	<0.2	<0.2	<0.2
Fluorene	0.1	<0.1	<0.1	1.2
Fluoranthene	<0.1	0.1	<0.1	0.1
Indeno(*1,2,3-c,d*)pyrene	<0.2	<0.2	<0.2	<0.2
Naphthalene	<0.1	<0.1	<0.1	<0.1
2-methyl-naphthalene	<0.1	<0.1	<0.1	<0.1
Phenanthrene	0.5	1.2	1.0	1.2
Pyrene	<0.1	0.1	0.1	0.1

Mr Ryan Medrana
Sinclair Knight Merz
ARL LAB No: 21857-67
27 October 2000

Lab No	21865	21866
Sample Mark	DE01809 C3	DE01809 C4
	mg/kg	
Acenaphthylene	<0.1	<0.1
Acenaphthene	<0.1	<0.1
Anthracene	<0.1	<0.1
Benzo(*a*)anthracene	<0.2	<0.2
Benzo(*ghi*)perylene	<0.2	<0.2
Chrysene	<0.2	<0.2
Benzo(*b*)fluoranthene	<0.2	<0.2
Benzo(*k*)fluoranthene	<0.2	<0.2
Benzo(*a*)pyrene	<0.2	<0.2
Dibenz(*a,h*)anthracene	<0.2	<0.2
Fluorene	<0.1	<0.1
Fluoranthene	<0.1	<0.1
Indeno(*1,2,3-c,d*)pyrene	<0.2	<0.2
Naphthalene	<0.1	<0.1
2-methyl-naphthalene	<0.1	<0.1
Phenanthrene	0.2	0.3
Pyrene	<0.1	<0.1

Kim Rodgers
Laboratory Manager

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.

ASLP EXTRACTION REPORT

ARL LAB No: 21857-67
DATE: 27 October 2000

CLIENT: Sinclair Knight Merz
263 Adelaide Terrace
PERTH WA 6001

ATTENTION: Mr Ryan Medrana

SAMPLE DESCRIPTION: Ten soil samples and ten dust samples as received for ASLP extraction and analysis of total phenols.

DATE RECEIVED: 18 October 2000

RESULTS:

DUSTS

Lab No	Sample Mark	Total Phenols
		mg/l
21857	DE01809 A1	0.12
21858	DE01809 A2	0.07
21859	DE01809 A3	0.07
21860	DE01809 A4	0.06
21861	DE01809 B1	0.15
21862	DE01809 B2	0.06
21863	DE01809 C1	0.11
21864	DE01809 C2	1.6
21865	DE01809 C3	0.06
21866	DE01809 C4	0.09

55 Wittenoom Street, East Perth, Western Australia 6004
Telephone: (08) 9221 1415 Facsimile: (08) 9325 2398
Email: arlwa@wanet.com.au
NATA Registration No. 2377

Mr Ryan Medrana
Sinclair Knight Merz
ARL LAB No: 21857-67
27 October 2000

SOILS

Lab No	Sample Mark	Total Phenols
		mg/l
21857	DE01809 A1	0.38
21858	DE01809 A2	0.51
21859	DE01809 A3	0.45
21860	DE01809 A4	0.30
21861	DE01809 B1	1.1
21862	DE01809 B2	0.35
21863	DE01809 C1	0.53
21864	DE01809 C2	1.4
21865	DE01809 C3	0.15
21866	DE01809 C4	0.45

Kim Rodgers
Laboratory Manager

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.

SINCLAIR KNIGHT MERZ 27 OCT 2000

LABORATORY REPORT

ARL LAB No: 22315-6
DATE: 25 October 2000

SINCLAIR KNIGHT MERZ				
ROLE	WHO	ACTION	SIGN	DATE
P.Mgr	RM	Sighted		27/10
JOB No.		FILE		

CLIENT: Sincalir Knight Merz
263 Adelaide Terrace
PERTH WA 6001

ATTENTION: Mr Ryan Medrana

SAMPLE DESCRIPTION: Two soil samples as received for analysis of moisture content.

DATE RECEIVED: 20 October 2000

RESULTS:

Lab No	Sample Mark	Moisture Content
		%
22315	A1M	10.5
22316	C1M	8.9

Kim Rodgers
Laboratory Manager

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.
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NATA Registration No. 2377

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.

LABORATORY REPORT

ARL Lab No: 21951-56
DATE: 23 OCTOBER 2000

CLIENT: Sinclair Knight Merz
7th Floor, Durack Centre
263 Adelaide Terrace
PERTH WA 6000

ATTENTION: Mr Ryan Medrana

DESCRIPTION: Six high volume air filters for analysis of total dusts as received.

RESULTS:

SAMPLE	TOTAL DUST mg
# 1	4.6
# 2	59.1
# 3	883.8
# 4	597.1
# 5	18.9
# 6	7.7

SINCLAIR KNIGHT MERZ				
RC F	WHO	ACTION	SIGN	DATE
PMGT	RMJ	Sighted	RM	25/10
	ROP	Seen	ROP	
		Approved for use	ROP	25/10
JOB No.		FILE		

25 OCT 2000

Kim Rodgers
Laboratory Manager

ANALYTICAL REFERENCE LABORATORY (W.A.) PTY. LTD.
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55 Wittenoom Street, East Perth, Western Australia 6004
Telephone: (08) 9221 1415 Facsimile: (08) 9325 2398
Email: arlwa@wanet.com.au
NATA Registration No. 2377

SINCLAIR KNIGHT MERZ

CHAIN OF CUSTODY RECORD

7th Floor, Durack Centre, 263 Adelaide Terrace, Perth WA 6000, Telephone:(09) 268 , Facsimile:(09) 268 4488

Project: Morangup Road Toodyay	Laboratory: ARL
Job No: DE01809	Laboratory Address:
Date: 20/10/00	55 Wittenoom Street, East Perth, WA 6004
Project Manager: Ryan Medrana	Laboratory Contact: Kim Rogers
Sampler: Ryan Medrana	Purchase Order Number: 10550
Signature: Rmedrana	Proper field sampling procedures have been observed during collection of these samples.

Sample ID	Depth	Date	Time	Sample Type	Container Type	Preservative Method	Storage Description	Analysis Request: Moisture Content	Analysis Request: Weight
A1M		19/10/00		Soil	Glass			X	
C1M		19/10/00		Soil	Glass			X	
21951		19/10/00		Filter	Plastic Bag				X
21952		19/10/00		Filter	Plastic Bag				X
21953		19/10/00		Filter	Plastic Bag				X
21954		19/10/00		Filter	Plastic Bag				X
21955		19/10/00		Filter	Plastic Bag				X
21956		19/10/00		Filter	Plastic Bag				X

1	Signature	Condition	Date	Time	Received by	Signature	**
R.Medrana	Rmedrana		20/10/00	8.30am			

Comments

Please save the dust samples collected on the filters. If possible, we may analyse the dust later.

k to confirm copy has been returned to Sinclair Knight Merz on event of every transfer

\\wenv\forms\coc.xls

h Floor, Durack Centre, 263 Adelaide Terrace, Perth WA 6000, Telephone:(09) 268 ...0, Facsimile:(09) 268 4488

Chain Of Custody Record

RECEIVED 18 OCT 2000 SINCLAIR KNIGHT MERZ By:

Project: Morangup Road Toodyay	Laboratory: ARL
Job No: DE01809	Laboratory Address: 55 Wittenoom Street, East Perth, WA 6004
Date: 18/10/00	
Project Manager: Ryan Medrana	Laboratory Contact: Kim Rogers
Sampler: Ryan Medrana	Purchase Order Number: 10549
Signature:	Proper field sampling procedures have been observed during collection of these samples.

Sample ID	Depth	Date	Time	Sample Type	Container Type	Preservative Method	Storage Description	Analysis Request: As per Fax Number 104rbmxx	Analysis Request: Storage
DE01809 A1		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 A2		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 A3		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 A4		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 B1		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 B2		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 C1		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 C2		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 C3		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 C4		17/10/00		Soil	Plastic Bag		Eskies	X	
DE01809 X		17/10/00		Soil	Plastic Bag		Eskies		X

#	Signature	Condition	Date	Time	Received by
R. Medrana		Good	18/10/00	8.30am	
K. ROGERS		Good	18/10/00	4.30 pm	

Comments: These results are required urgently, could you please get them to me as soon as possible.

Signature: ROLE WHO ACTION P.Mgr Rm

JOB No: FILE:

* Tick to confirm copy has been returned to Sinclair Knight Merz on event of every transfer

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P.01/01 92684488 TO ARL W.A. PTY LTD FROM 10:46 18-OCT-2000 TOTAL P.01

CLAIR KNIGHT MERZ

CHAIN OF CUSTODY RECORD

Job N° 54537.

Page 1 of 1

xx, Durack Centre, 263 Adelaide Terrace, Perth WA 6000. Telephone:(09) 268 4400. Facsimile:(09) 268 4488

ect: Morangup Road, Toodyay	Laboratory: AEL
No: DEO1809	Laboratory Address:
: 18/10/00	52 Murray Road, Welshpool 6106
ect Manager: R Medrana	Laboratory Contact: Rick Staker
pler: R Medrana	Purchase Order Number:
nature: Rmedrana	Proper field sampling procedures have been observed during collection of these samples.

Sample ID	Depth	Date	Time	Sample Type	Container Type	Preservative Method	Storage Description	Storage	Analysis Request
01809 Y		17/10/00		Soil	Plastic Bag			x	

SINCLAIR KNIGHT MERZ PERTH AUSTRALIAN ENVIRONMENTAL

	Signature	Condition	Date	Time	Received by	Signature	**
1 R Medrana	Rmedrana	Good	18/10/00	1110	M. DANIES		
2 E. Baxter	EBaxter	Good	18/10/00	11:35			

Tick to confirm copy has been returned to Sinclair Knight Merz on event of every transfer

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Comments

This sample may require analysis at a later date.
Could you please put it into storage

SINCLAIR KNIGHT MERZ				
ROLE	WHO	ACTION	SIGN	DATE
PM	RM	sighted	RM	18/10

18-OCT-2000 01:18

18/10 '00 WED 13:03 [TX/RX NO 9304] 001

TOTAL P.01

********** -COMM. JOURNAL- ********** DATE 18-OCT-2000 ***** TIME 00:05 *** P.01

MODE = MEMORY TRANSMISSION START=18-OCT 00:02 END=18-OCT 00:05
FILE NO.= 063

STN NO.	COM	ABBR NO.	STATION NAME/TEL.NO.	PAGES	DURATION
001	BUSY	S	92684488	000/001	00:00'00"

-AUSTRALIAN ENVIRONMENTAL -

********** -4R- ***** - 61 8 9451 3505- *****

Appendix D Dust Monitoring Results

Sample	Measured Concentration (ug/m3)	Sample Time (seconds)	Dust Weight (mg)	Sampling Time (min)	Weight due to Background (mg)	Dust mass due to test (mg)	Number of plume hits #	Mass per Hit (mg)
	High Volume Sampler							
Site A, Wet	na for DustTrak		59.1	11.5	1.181	57.9	3.125	18.5
Site A, Dry	na for DustTrak		883.8	3.25	0.334	883.5	2.625	336.6
Site C, Dry	na for DustTrak		597.1	4	0.411	596.7	3.5	170.5
Site C, Wet	na for DustTrak		18.9	10	1.027	17.9	4.125	4.3
	DustTrak at HiVol							
Site A, Wet	678.4	622	0.38	10.37	0.007	0.4	3.125	0.1
Site A, Dry	13179.3	284	16.04	4.73	0.015	16.0	2.625	6.1
Site C, Dry	7644.9	254	10.40	4.23	0.017	10.4	3.5	3.0
Site C, Wet	69.1	604	0.04	10.07	0.007	0.0	4.125	0.0
	DustTrak #2							
Site A, Wet	1553.9	620	0.87	10.33	0.007	0.9	5.25	0.2
Site A, Dry	26307.7	289	31.46	4.82	0.015	31.4	3.75	8.4
Site C, Dry	4792.5	266	6.23	4.43	0.016	6.2	2.5	2.5
Site C, Wet	92.9	616	0.05	10.27	0.007	0.0	1.75	0.0

Site	Ground	HiVol (TSP) weight (mg)	Sample Time (minutes)	Hivol (TSP) conc (ug/m3)	DusTrak (PM10) at HiVol (ug/m3)	DusTrak (PM10) #2 (ug/m3)
Background		4.6	71	56	13	not used
A	wet	59.1	11.5	4,405	678	1,554
A	dry	883.8	3.25	233,090	13,179	26,308
C	dry	597.1	4	127,950	7,645	4,792
C	wet	18.9	10	1,620	69	93
Background		7.7	55	120	12	not used

Appendix E Quality Assurance Documentation

JAS-ANZ

QAS is Accredited by the Joint Accreditation System of Australia and New Zealand. Acc No. S1250992AS

Quality System

Quality Endorsed Company

IQNet CERTIFIED MANAGEMENT SYSTEM

CERTIFICATE OF REGISTRATION

Sinclair Knight Merz Pty Limited

ACN 001024095

100 Christie Street ST LEONARDS NSW 2065

(Refer to Schedule of Addresses No. QEC0600 dated 15 March 2000 for additional certified sites)

complies with the requirements of

AS/NZS ISO 9001 : 1994

Quality systems-Model for quality assurance in design development production installation and servicing

for the following capability

The registration covers the Quality Management System for the provision of consulting services to commerce, industry and public sector organisations.

Consulting services include, but are not limited to, investigation, planning, design, engineering, economic and financial analysis, construction management, operations, maintenance, expert advice and project management, in the following business areas:

Energy and communications; Industrial and building materials; Spatial, including GIS, data capture, mapping and information management; Minerals, including mining, materials handling and metal product manufacture; Environment planning, engineering and management; Buildings and structures; Infrastructure and Defence; Advisiory, including board room consulting and specialist strategic services.

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Subject to the QAS Terms and Conditions for Certification. While all due care and skill was exercised in carrying out this assessment, QAS accepts responsibility only for proven negligence. This certificate remains the property of QAS and must be returned to QAS upon its request.

Certificate No.: QEC0600
Issue Date: 15 March 2000

Certified Date: 1 February 1993
Expiry Date: 12 August 2001

Keith Ketheeswaran
Managing Director
For and on behalf of
The Board of Quality Assurance Services Pty Limited

QAS
QUALITY ASSURANCE SERVICES

Authorised Local Signatory, QAS

MKBI8.01

JAS-ANZ

Quality System

Quality Endorsed Company

CERTIFIED IQNet MANAGEMENT SYSTEM

SCHEDULE OF ADDRESSES

Sinclair Knight Merz Pty Limited

ACN 001024095

MTIA House Ground Floor 214 Northbourne Avenue BRADDON ACT 2612 AUSTRALIA
Level 6 FNPF Place Victoria Parade SUVA GPO 11428 FIJI
369 Ann Street SPRING HILL QLD 4000 AUSTRALIA
49 Annand Street TOOWOOMBA QLD 4350 AUSTRALIA
East Quay Corporate Park 34-36 Glenferrie Drive ROBINA QLD 4226 AUSTRALIA
131 Denham Street TOWNSVILLE QLD 4810 AUSTRALIA
28 Miles Street MT ISA QLD 4825 AUSTRALIA
2 James Street CAIRNS QLD 4870 AUSTRALIA
100 Christie Street ST LEONARDS NSW 2065 AUSTRALIA
Durack Centre 263 Adelaide Terrace PERTH WA 6000 AUSTRALIA
Tonella Commercial Centre 125 Bull Street NEWCASTLE WEST NSW 2302 AUSTRALIA
590 Orrong Road ARMADALE VIC 3143 AUSTRALIA
40 Casey Street TATURA VIC 3616 AUSTRALIA
99 Hannan Street KALGOORLIE WA 6430 AUSTRALIA
20 Ellerslie Road BATTERY POINT TAS 7004 AUSTRALIA
54 Paterson Street LAUNCESTON TAS 7250 AUSTRALIA
215 Port Road HINDMARSH SA 5007 AUSTRALIA
1st Floor Bayly House Nede Street LAUTOKA FIJI
34 McLachlan Street DARWIN NT 0801 AUSTRALIA

Registered by:

Quality Assurance Services Pty Limited (QAS) ACN 050 611 642 1 The Crescent Homebush NSW 2140 Australia
Subject to the QAS Terms and Conditions for Certification. While all due care and skill was exercised in carrying out this assessment, QAS accepts responsibility only for proven negligence. This certificate remains the property of QAS and must be returned to QAS upon its request.

Certificate No.: QEC0600
Issue Date: 15 March 2000

Certified Date: 1 February 1993
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QAS
QUALITY ASSURANCE SERVICES

MKB18.01

NATIONAL ASSOCIATION OF TESTING AUTHORITIES

AUSTRALIA

This is to Certify that

THE PERTH LABORATORY

OF

ANALYTICAL REFERENCE LABORATORY (WA)

has been accepted by the Council of the Association as a

Registered Laboratory

The laboratory has been registered for specific tests within the field of

Chemical Testing

The COMMON SEAL of NATIONAL ASSOCIATION OF TESTING AUTHORITIES, AUSTRALIA was affixed hereto by authority of the Council of the Association in the presence of—

J. A. GILMOUR, Registrar

Date of Registration 19 APRIL 1988

Registered Number 2377

TOTAL P.01

04/10 '00 WED 09:42 [TX/RX NO 9236] ☑001

NATIONAL ASSOCIATION OF TESTING AUTHORITIES, AUSTRALIA

ACCREDITATION NUMBER : 2377

Analytical Reference Laboratory (WA) Pty Ltd
Perth Laboratory

55 Wittenoom Street
EAST PERTH WA 6004

CONTACT : Mr D Williams
Phone : (08) 9221 1415 Fax : (08) 9325 2398

FACILITIES : Public testing service

7.52 Residues in foods and agricultural materials

.02 Pesticides

Analysis of organochlorine and organophosphorus residues
in meat fat
for the following determinations -
Aldrin; α, β and δ BHC; bromophos ethyl; cis and trans chlordane;
chlorpyrifos; DDD; DDE; DDT; dieldrin; α and β endosulphan; endrin;
ethion; HCB; heptachlor; heptachlor epoxide; lindane; methoxychlor;
oxychlordane

Analysis of organochlorine and organophosphorus residues in grains
Analysis by GC techniques
by the methods of -
in-house 004
for the following determinations -
Aldrin; α, β and δ BHC; cis and trans chlordane; DDD; DDE; DDT;
dieldrin; α and β endosulphan; endosulphan sulphate; endrin; HCB;
heptachlor; heptachlor epoxide; lindane; oxychlordane

7.66 Waters

Analysis by classical and AAS (flame) techniques
by the methods of -
in-house
for the following determinations
Anionic surfactants; biochemical oxygen demand; chemical oxygen demand;
chloride; conductivity; elements as listed 7.84.01; oil and grease; pH;
solids-suspended, total; sulphate

.01 Waters for potable and domestic purposes
.02 Waters for irrigation and stock
.03 Waters for industrial and steam-raising purposes
.05 Trade wastes

7.81 Constituents of the environment

.11 Waters other than saline
Elements as listed in 7.84.01

.31 Soils
Elements as listed in 7.84.01

7.82 Workplace environment and hazards

.01 Asbestos fibre counting
Estimation of airborne asbestos dust by the membrane filter method described in the National Occupational Health and Safety Commission Guidance Note (1988) and laboratory method ASBMON

.31 Asbestos identification
Qualitative identification in bulk samples
Analysis by Polarised Light Microscopy (including dispersion staining) techniques
by the methods of -
in-house method ASBID
for the following determinations -
Amosite; chrysotile; crocidolite

.81 Volume measurement (air)
for tests under 7.82.01

7.84 Residues in constituents of the environment

.01 Elements
Analysis by AAS (flame) techniques
by the methods of -
In-house methods No 27, 29, 30, 31
for the following determinations -
Arsenic; cadmium; chromium; copper; lead; manganese; nickel; zinc

.02 Pesticides
Analysis of soils and waters
Analysis by GC techniques
by the methods of -
in-house methods 002, 003
for the following determinations -
Aldrin; α, β and δ BHC; cis and trans chlordane; chlorpyrifos;
DDD; DDE; DDT; dieldrin; α and β endosulphan; endosulphan sulphate;
endrin; HCB; heptachlor; heptachlor epoxide; lindane; methoxychlor; oxychlordane

.03 Polyhalogenated biphenyls
Analysis of soils and waters
Analysis by GC techniques
by the methods of -
in-house methods 002, 003
for the following determinations -
Aroclor 1016; 1242; 1254; 1260; 1262

.12 Petroleum hydrocarbons
Analysis of soils and waters
Analysis by GC techniques
by the methods of -
in-house methods 009, 010
for the following determinations -
Dichloromethane extractable petroleum hydrocarbons

.21 Monocyclic aromatic hydrocarbons
Analysis of soils and waters
Analysis using GC techniques
by the methods of -
in-house methods 007, 008
for the following determinations -
Benzene; ethylbenzene; toluene; xylenes

.22 Polycyclic aromatic hydrocarbons
Analysis of soils and waters
Analysis by GC/MS techniques
by the methods of -
in-house methods 005, 006

Data change date 02/03/98

Accreditation Number 2377
- printed 4/3/98

NATA scope of Accreditation Inorganic Section ARL(WA)

Class and Sub-class	Test	Method ARL No	Technique	Accreditation
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Nitrate in water	32	Reduction, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Nitrite in water	33	colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Nitrogen-Organic in water	34	Digestion, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,12	Nitrogen-Ammonia in water	35	Distillation, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Phosphorus in water	36	Digestion, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06	Alkalinity in water	37	Titrimetric	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81,.11,.12,.31,.32,.33	Cyanide Total in water and soil	63	Digestion, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Cyanide Weak acid Dissociable in water	62	Digestion, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Cyanide Total available in water	60	Titrimetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Cyanide Total available in water	61	Colourmetric	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Metals in water by extraction*	38	Extraction/AAS	Awaiting NATA
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Silica in water	67	Colourmetric	Awaiting NATA

Class and Sub-class	Test	Method ARL No	Technique	Accreditation
7.66,.01,.02,.04,.05,.06 7.81.11,.12,.31,.32,.51	Mercury	39	Cold Vapour	Awaiting NATA
7.66,.01,.02,.04,.05,.06 7.81,.31,.32,.51	Arsenic	40	Hydride	Awaiting NATA
7.66,.01,.02,.04,.05,.06 7.81,.31,.32,.51	Antimony	66	Hydride	Awaiting NATA
7.66,.01,.02,.04,.05,.06 7.81,.31,.32,.51	Selenium	65	Hydride	Awaiting NATA
7.66,.01,.03,.04,.05,.06 7.81.11	Phenols in waters	44	Distillation, colourmetric	Awaiting NATA
7.66,.01,.02,.03,.05,.06 7.81.11,.12	Turbidity in waters	45	Nephelometric	Yes
7.66,.01,.02,.03,.04,.05,.06	Hexavalent chromium in waters	50	colourmetric	Awaiting NATA
7.66.01,.02,.03,.04,.05,.06 7.81.11,.12	Total Solids Dried at 103-105°C	017	Gravimetric	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Chloride	018	Argentometric	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Conductivity in waters	019	Electrical	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Chemical Oxygen Demand	020	Closed Reflux, Titrimetric	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	pH in waters	014	Electrode	Yes
7.66.04,.05	Anionic Surfactants	25	MBAS	Yes

Class and Sub-class	Test	Method ARL No	Technique	Accreditation
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12 7.84.01	Metals** in water	29	AAS	Yes
7.81.31,.32,.33 7.84.01	Metals** in soils/sediments/ solid waste	27,30,31	AAS	Yes
7.66.04,.05	Oil & Grease	15	gravimetric	Yes
7.66.04,.05	Total suspended solids	16	gravimetric	Yes
7.66.04,.05	BOD	11	Electrode	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Sulphate	28	Turbidimetric	Yes
7.66,.01,.02,.03,.04,.05,.06 7.81.11,.12	Dissolved oxygen	12,13	Electrode/titration	Awaiting NATA
7.81.31, .32, .33	TCLP	69	Extraction	Awaiting NATA

- Metals Extraction
  Methods; ARL No 38

  Aluminium, cadmium, cobalt, copper, lead, iron, silver, vanadium, zinc.

** Metals water, sediments & soils
Methods; ARL No 027, 029, 030, 031

Aluminium, antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, lead, iron, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, strontium, vanadium, zinc, tin.

Metals underlined have accreditation.

Barbara Wraith of NATA has indicated that approval for all the tests will be granted shortly. Her contact number is 9451 0883.