ENVIRONMENTAL REVIEW

WESTERN AUSTRALIAN PLANNING COMMISSION

METROPOLITAN REGION SCHEME
AMENDMENT NO. 999/33
NORTHBRIDGE URBAN RENEWAL

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ENVIRONMENTAL REVIEW

INVITATION TO COMMENT ON THIS ENVIRONMENTAL REVIEW

The Western Australian Planning Commission (WAPC) invites people to make a submission on this Environmental Review.

This document describes a proposal by the Western Australian Planning Commission to manage the issue of contaminated soil in the Northbridge Redevelopment Area. The area was previously used for a variety of industrial, commercial and residential purposes which have resulted in the contamination of the soil. The land is to be remediated to a standard which will allow a mixture of commercial and residential development.

In accordance with the Environmental Protection Act, 1986 this document has been prepared to describe the proposal and its likely effects on the environment. The document is available for a public review period of 60 days from 1 October 1999, closing on 29 November 1999.

After receipt of comments from Government Agencies and the Public the WAPC will forward submissions to the EPA.

Comments from government agencies and from the public will assist the EPA to prepare an assessment report in which it will make recommendations to the Minister for the Environment.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in each report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If you group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the document or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the document:

- clearly state your point of view;
- indicate the source of your information or argument if this is applicable;
- suggest recommendations, safeguards or alternatives.

Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- attempt to list points so that the issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the document;
- if you discuss different sections of the document, keep them distinct and separate, so there is no confusion as to which section you are considering;
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name,
- address,
- date, and
- whether you want your submission to be confidential.

The closing date for submission is 29 November 1999.

Submissions should be addressed to:

Western Australian Planning Commission
469-489 Wellington Street
PERTH WA 6000

Attention: Shernaz Udwadia
Project Officer

Phone: 9264 7613

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EXECUTIVE SUMMARY

This Environmental Review (ER) describes a proposal by the Western Australian Planning Commission to redevelop 15.5 hectares of land above and adjacent to the Northbridge Tunnel. The land will be redeveloped for a variety of residential, commercial and entertainment uses. A minor amendment to the Metropolitan Region Scheme from Controlled Access Highway to Central City Area is required to permit subdivision of the land and sale of individual subdivided lots.

The redevelopment area has been the subject of two major environmental investigations, one relating to the tunnel alignment and the second for the land adjacent to the alignment. Localised soil contamination has been detected by these investigations. The contamination is principally in the form of heavy metals, in particular lead.

Contamination along the tunnel alignment was removed as part of the tunnel excavations. Contamination in the adjoining land has not yet been dealt with and is the subject of this Environmental Review.

The Environmental Review describes the management approach that will be adopted to ensure that all lots are suitable for residential use. The contamination has been assessed against both environmental and human health investigation levels and been subject to a preliminary health risk assessment. The Environmental Review nominates environmental protection criteria as clean-up or response levels for the contamination assuming a residential redevelopment scenario. However, application of a site specific health risk assessment may be undertaken at suitable sites to demonstrate a human health based approach to remediation. This would be performed to the satisfaction of the DEP.

The overall aim of the proposed management strategy is to ensure that any soil retained is suitable for residential use prior to development. This can be achieved by clean-up to environmental protection standards or where no risk is posed to the environment, to standards protective of human health.

It is proposed that the majority of the identified contamination will be remediated to the ANZECC B Environmental Investigation Threshold. This will be done prior to development of the property.

Provisions will be made in the Town Planning Scheme in the form of a schedule to ensure that properties that are not remediated up to ANZECC B levels prior to sale will be remediated before redevelopment. Should sites be subject to a health risk assessment, they will remain on the schedule with memorials placed on Titles. This approach is better suited for commercial and high density residential developments. Property developers will be required to conform to the management process described in this Environmental Review.

The proponent considers the proposed remediation is consistent with maintenance of the environment and protection of human health. In order that the land is suitable for residential development, a number of environmental management commitments have been made. The following table lists the environmental management measures the proponent is committed to implement.

TABLE 1

LIST OF ENVIRONMENTAL COMMITMENTS

Environmental Management Measure	Category	Topic	Objectives	Proposed Management Measure	Key Agency *
1.	Pollution Potential	Environmental Sampling	• To assess the nature and extent of soil contamination in areas not previously assessed or sufficiently assessed as part of the initial environmental investigations.	• Undertake soil sampling.	DEP
2.	Pollution Potential	Health Risk Assessment	• To assess the soil contamination in terms of risk to human health based on site specific conditions.	• Perform a health based risk assessment in locations where soil contamination in excess of the ANZECC B Investigation threshold is to be retained. • Place memorials on Titles where contamination in excess of ANZECC B is to be retained.	DEP HDWA
3.	Conformance	Remedial Works	• To ensure contaminated sites are redeveloped in accordance with the approach outlined in this Environmental Review.	• Maintain a Contaminated Site Schedule which includes all lots where residual soil contamination exceeds the ANZECC B level or where the status is unknown.	LA
4.	Pollution Potential	Remedial Works	• To minimise the exposure of workers, the public and the environment to contaminated soil.	• Removal of contaminated soil in accordance with the site management techniques described in the ER • All contaminated soils removed from the site will be disposed of in accordance with Landfill Waste Classification and Waste Definitions.	DEP Worksafe-WA
5.	Waste Management	Contaminated Soil Transport	• To minimise the risk of transporting contaminated soil from the site.	• All contaminated soil transported from the site will be carried in a manner consistent with the Dangerous Goods Regulations.	DEP DME
6.	Waste Management	Destination of Waste Materials	• To ensure all contaminated soil from the site is managed and disposed in a manner which reduces environmental impact and risk to human health.	• The ultimate destination of all contaminated soil will be selected on the basis of criteria set by the Landfill Waste Classification and Waste Definitions.	DEP

Environmental Management Measure	Category	Topic	Objectives	Proposed Management Measure	Key Agency *
7.	Pollution Potential	Dust Discharges	• To ensure that dust discharges during the remediation phase comply with regulatory standards.	• Dust discharges from the site will be kept within EPA criteria.	DEP
8.	Conformance	Vibration	• To ensure vibration does not affect residents or damage nearby properties.	• Vibration will be kept to a minimum and comply with the Australian Standard.	DEP
9.	Conformance	Remedial Works	• To ensure compliance with EPA approved clean-up criteria.	• A validation program of the remedial works will be implemented to demonstrate compliance with EPA site clean-up criteria.	DEP
10.	Conformance	Conformance Report	• To document site clean-up has been performed in accordance with EPA requirements.	• A report at the completion of the validation program will be submitted to the DEP which will provide evidence of conformance to the management measures and environmental conditions for the project.	DEP

*** Agency Summary:**

DEP	Department of Environmental Protection
EPA	Environmental Protection Authority
HDWA	Health Department of Western Australia
LA	Local Authority
Worksafe WA	

1. INTRODUCTION

1.1 BACKGROUND

The land corridor along which the Northbridge tunnel is located is presently zoned Controlled Access Highway under the Metropolitan Region Scheme (MRS). This zoning was put in place at a time when the City Northern Bypass (Graham Farmer Freeway) was to be constructed at street level. The decision to place the freeway in an underground tunnel has released approximately 15.5 hectares of land above the tunnel that may now be developed.

The future land use for the Northbridge redevelopment area is residential, commercial and entertainment. A minor amendment to the MRS from Controlled Access Highway to Central City Area will be required to permit subdivision of the land and sale of individual subdivided lots. The Western Australian Planning Commission (WAPC) is the Responsible Authority for the scheme amendment.

The WAPC referred the MRS amendment to the Environmental Protection Authority in accordance with clause 33E of the Metropolitan Region Town Planning Scheme Act. The EPA advised the WAPC that the amendment would be subject to formal assessment under Section 48A of the Environmental Protection Act. This level of assessment requires the preparation of this Environmental Review which is released to the general public for comment. The environmental factor identified by the EPA is soil contamination, and is the focus of this report.

Soil contamination in the area was suspected due to a history of industrial and commercial uses. Two preliminary (Phase I) soil contamination investigations have been undertaken in the Northbridge Redevelopment Area. Both investigations identified soil contamination.

The first investigation was undertaken in 1997 and 1998 (HGM 1998) in which soil contamination along the tunnel alignment was assessed. The primary contaminants were the heavy metals zinc and lead. Contamination was not clearly associated with previous or current land use. The distribution of contaminants indicated that soil contamination within the remainder of the redevelopment area was likely. All contaminated soil above the tunnel alignment was removed during tunnel construction and clean fill material placed on top of the tunnel.

The second soil investigation (Egis, 1999) assessed the nature and extent of contamination along either side of the tunnel alignment. The collection of soil samples was limited to locations that were readily accessible and lots not privately owned. The assessment identified areas of contamination or potential contamination, and locations with no evidence of soil contamination.

This Environmental Review describes the management approach that will be adopted to ensure that all lots are suitable for standard residential use. The EPA required that the Western Australian Planning Commission (WAPC) prepare this Environmental Review in order to provide information about the project to the general public and to assist the EPA in the preparation of an Assessment Report for the Minister for the Environment. The public is encouraged to provide written comment to the WAPC as part of the scheme amendment process (of which this environmental review is a part) during the public review period. The scheme amendment is described in more detail in Section 2.

1.2 OBJECTIVES OF THE ENVIRONMENTAL REVIEW

The Environmental Review has been prepared in accordance with the instructions issued by the EPA (Appendix A) with the following objectives:

- describe the proposed scheme amendment and the status of the environment affected by the amendment;
- to ensure the proposed scheme amendment area is rehabilitated consistent with the intended landuses;
- to set out the specific environmental impacts that the proposal may have; and
- for each impact, to describe how the proponent would avoid, mitigate or ameliorate that impact.

1.3 ASSESSMENT PROCESS

The assessment process for a non-substantial (minor) amendment under Section 33A of the Metropolitan Region Town Planning Scheme is shown in Figure 1.

An amendment is initially referred to the EPA where a decision on the level of assessment is made. The EPA may elect not to assess the proposal, set a formal level of assessment or determine that the amendment is environmentally unacceptable. A formal level of assessment will require the preparation of an Environmental Review. An Environmental Review is required to provide information on environmental implications relating to the proposal and outline procedures for environmental management. They are structured and intended for distribution to the general public for review and comment. The environmental assessment process runs in parallel with the assessment of the scheme amendment by the Minister for Planning.

The public review process commences with the EPA approving the release of the Environmental Review. The Environmental Review is released at the same time as the amendment. Written submissions from individuals, groups and government departments can be made to the WAPC during the 60 days public review period. Those submissions relating to Environmental issues are forwarded to the EPA.

The WAPC provides a response to the points raised in the public submissions and these responses are then incorporated into the EPA assessment of the amendment. Subsequently the EPA reports to the Minister for the Environment on the environmental factors relevant to the amendment and on the conditions and procedures to which the proposal should be subject, if implemented.

Having received advice from the EPA, the Minister then consults with the Ministry for Planning and sets agreed environmental conditions for the amendment. The EPA is usually advised in its assessments by the DEP. The Minister for Planning approves or declines the amendment as part of the town planning process.

1.4 TIMING OF THE AMENDMENT

Development of the Northbridge Redevelopment Area will commence after all necessary environmental and planning approvals have been obtained. Development will occur in a staged manner over several years.

1.5 ENVIRONMENTAL ISSUES

The environmental factor of concern identified by the EPA is soil contamination. Significantly contaminated soil has the potential to compromise environmental qualities and to pose a threat to human health through direct contact or inhalation in the case of volatile compounds. No other factors are considered by the EPA as being of major significance to the proposal.

The level of contamination has been assessed against environmental investigation levels which are protective of sensitive landuses and the underlying groundwater.

The risk posed by the residual contamination to human health has been assessed in a detailed health risk assessment (HRA) Appendix D. Where remediation is required, measures for the extraction and disposal of the contaminated material are proposed. These are designed to ensure on-going protection of human health and the environment during the clean-up operation.

1.6 MANAGEMENT STRATEGY

The proposed management strategy will ensure that the soil on all lots is suitable for standard residential landuse prior to development. The management approach for the Northbridge Redevelopment Area is summarised as follows.

Lots in the scheme amendment which will require management include:

- those lots identified during the current investigations as containing contaminated soil in excess of the environmental investigation level,
- those lots for which there is insufficient site information to confirm the site as clean or contaminated. This will include land that is currently privately owned.

The proposed approach to remediation is to remove contaminated soil in excess of the environmental investigation level or criteria determined by a site specific health risk assessment endorsed by the DEP.

Soil contamination exceeding the proposed clean-up criteria will be remediated to the requirements of the DEP prior to development. In most cases this will be done by the proponent prior to the sale of the relevant properties.

Lots identified as meeting the environmental investigation level require no special management. Soil within the area over of the tunnel alignment has been verified as clean and in conformance to this criteria.

Provisions will be made in the Town Planning Scheme to ensure that properties that are to be sold in a contaminated (or potentially contaminated) state will be investigated and remediated accordingly prior to development. The developer will be required to conform to the management process described in this Environmental Review.

A full description of the proposed management approach is described in Section 6.

1.7 DOCUMENT STRUCTURE

The following sections provide information on the scheme amendment and the management of soil contamination. Section 2 summarises the scheme amendment. Section 3 provides background to the proposal in relation to the site history, hydrogeology and investigations of contamination. Section 4 outlines the contaminants and sets out the criteria used for assessing contamination. Section 5 describes the nature and extent of the contamination. The approach to environmental management is described in Section 6 and the environmental management measures during remediation are set out in Section 7. Commitments to meet this approach are made in Section 8.

References are provided in Section 9 followed by abbreviations and referral to figures quoted to in the report. Appendices present the EPA Instructions for this proposal, the preliminary health risk assessment for the project, the results of recent 1999 environmental investigations and the quality assurance program related to past and recent environmental investigations.

2. SUMMARY OF AMENDMENT

2.1 LOCATION

The Northbridge Redevelopment Area (NRA) is located within a narrow corridor running between Aberdeen and Newcastle Streets, between Fitzgerald and Beaufort Streets in the west, then realigning between Newcastle and Parry Streets, between William and Lord Streets in the east. Figure 2 shows the proposed redevelopment area. The land lies within the City of Perth and Town of Vincent local government areas.

The majority of properties within the NRA have been acquired by the WAPC. Other property owners are the Main Roads Western Australia, Minister for Training, City of Perth and Town of Vincent. Twenty properties in the redevelopment area are privately owned.

The current landuses on either side of the tunnel alignment are residential and commercial. Commercial landuse is focused along the western half of the redevelopment area. Residential landuse is primarily to the east of the redevelopment area.

The land above the Northbridge tunnel is cleared.

2.2 AMENDMENT

The scheme amendment has been initiated to:

- transfer the land on top of the Northbridge tunnel from Controlled Access Highways reservation to zones which reflect the surface land use, and
- amend the zoning in the MRS to the Central City Zone (City of Perth) and the Urban zone (Town of Vincent). These zonings will allow a variety of landuse including residential.

The MRS will not reflect the underground tunnel as a zone or as a reserve.

The proposed land uses are configured with residential uses toward the eastern and western ends of the Northbridge Urban Renewal Area, and commercial and entertainment uses toward the middle of the area. The proposed subdivision is shown in Figure 3.

3. BACKGROUND

3.1 INTRODUCTION

This section describes the history of the redevelopment area, soil conditions and hydrogeology. Included is a summary of environmental investigations performed to date.

3.2 SITE HISTORY

European occupation in Northbridge dates back to the early settlement and development of Perth. Historical and archaeological studies of former land uses and activities along the NRA show a mixture of residential, industrial and commercial from the time of first settlement (Baulderstone Clough Joint Venture-BCJV, 1996) (Rust PPK, 1995).

The past and current land uses that have been identified as having the potential to create soil contamination include:

- car yards,
- fish cleaner,
- furniture restoration and store,
- dry cleaners,
- galvanising factory,
- bakery,
- motor repairs,
- pest control, and
- possible filling of sites.

Figure 4 shows location of past and current landuses.

3.3 SITE LAYOUT

For ease of reference, the redevelopment area has been divided into nine blocks conveniently bounded by roads and are identified as Blocks A through to I.. The location of the blocks are:

Block A – 0.6 ha bounded by Newcastle Street to the north, Aberdeen to the south, Fitzgerald Street to the east and the western tunnel entry.

Block B – 2.4 ha bounded by Newcastle Street to the north, Aberdeen to the south, Palmerston Street to the east and Fitzgerald Street to the west.

Block C – 1.85 ha bounded by Newcastle Street to the north, Aberdeen to the south, Lake Street to the east and Palmerston Street to the west.

Block D – 2.2 ha bounded by Newcastle Street to the north, Aberdeen to the south, William Street to the east and Lake Street to the west.

Block E – 2.85 ha bounded by Newcastle Street to the north, Aberdeen to the south, Lake Street to the east and Beaufort Street to the west.

Block F – 2.0 ha bounded by Newcastle Street to the south, Beaufort Street to the east, William Street to the west and including properties along Money and Lindsay Streets generally as far north as Parry Street.

Block G – Weld Square (1.0 ha), bounded by Parry street to the north, Newcastle Street to the south, Stirling Street to the east and Beaufort Street to the west.

Block H – 1.05 ha bounded by Parry street to the north, Newcastle Street to the south, Pier Street to the east and Stirling Street to the west.

Block I – 2.55 ha bounded by Parry Street to the north, Newcastle Street to the south, Lord Street to the east and Pier Street to the west.

The site comprises a mixture of occupied residential and commercial premises, vacant properties, cleared lots used for construction purposes, and carparking areas. Large areas of land in the redevelopment area are covered by concrete and bitumen surfaces and buildings.

3.4 GEOLOGY AND SOILS

The Northbridge redevelopment area ranges in surface elevation from 10 m to 18 m AHD and is underlain by sediments of the Quaternary period. The superficial formation is the Spearwood Dune geomorphological unit which is of aeolian origin (GSWA, 1986). The lithology of this area is characterised by pale and olive yellow, medium to coarse grained quartz sand with minor shell fragments derived from Tamala Limestone.

A portion of the redevelopment in the region of block F is associated with swamp deposits located within an interbarrier depression of lacustrine origin. The lithology is characterised by peaty sand, dark grey and black quartz and variable organic content.

3.5 HYDROGEOLOGY

The direction of groundwater flow is between the south and southeast towards the Swan River (Perth Groundwater Atlas, WRC, 1997). The depth to the permanent watertable depends upon land elevation and location and ranges from 1 m in low lying areas to a maximum of 10 m. The estimated maximum water table elevation in the eastern part of the redevelopment is 9 m AHD and 13 m AHD in the west.

3.5.1 Potential for Groundwater Contamination

The NRA is considered to have a high to very high vulnerability to groundwater contamination due to the shallow depth to watertable and permeable nature of the surface soils. This classification is based upon the groundwater Vulnerability to Contamination Maps of the Perth Basin, GSWA Record 1993/6.

3.6 ENVIRONMENTAL INVESTIGATIONS

Parts of the Northbridge redevelopment area have been contaminated with chemical compounds resulting from past industrial and commercial activities. There have been a number of environmental investigations over the past four years. These investigations were initiated in order to fulfil the environmental management requirements for the development of the Northbridge tunnel. These investigations are summarised as follows with more detail provided in Table 2:

- 1995 Desktop study investigating the potential for soil contamination.
- 1996 Desktop study investigating the potential for soil contamination.
- 1997/1998 Assessment of the nature and extent of the contamination above the tunnel alignment.
- 1999 Assessment of soil contamination on lots located on either side of the tunnel alignment and within the redevelopment area.

The following sections describe the results of environmental investigations and provide an assessment of the contamination status of the soil in the redevelopment area against relevant human health and environmental protection criteria. A full outline of the 1999 investigations are provided in Appendix B.

TABLE 2
SUMMARY OF ENVIRONMENTAL INVESTIGATIONS TO DATE

DATE	INVESTIGATION
1995	Consultants Rust PPK conducted a desktop review of recent and historical landuses along the Northbridge Tunnel alignment. *Background Study on Potential Contaminated Sites – Burswood Bridge and Road Project. Rust PPK. April 1995.*
1996	BCJV conducted searches of archival information held by the Building Approvals section of the City of Perth. *Archaeological Investigations Stage. Baulderstone Clough Joint Venture. REP/24/g/2022/2, September 1996.*
1996-1998	Consultants HGM conducted site investigations along the Northbridge Tunnel alignment in a staged manner between early 1996 and late 1997. Soil samples were collected on a 10m grid. A preliminary assessment of soil contamination utilised previous desktop investigations and the site soil analysis results. *Northbridge Urban Renewal Project Preliminary Soil Contamination Assessment. Halpern Glick Maunsell. January 1998.*
1999	Consultants Egis Consulting Australia conducted a soil contamination assessment on the lots either side of the tunnel alignment and within the redevelopment area. *Results tabled in this report in Appendix B.*

3.6.1 Environmental Sampling Quality Control

Environmental sampling requires specific sampling techniques and a high level of quality control. Sampling protocols ensure that the samples submitted for laboratory analysis have been sampled in the appropriate manner and are truly representative of the conditions. Quality control includes laboratory reanalysis of a number of samples and decontamination procedures for sampling equipment to ensure there has been no cross contamination between sample locations.

With regard to those studies that have been used to determine the contamination status of the site, soil samples were taken using appropriate methods of sampling, handling and transport of samples and decontamination or cleaning procedures for sampling equipment.

All samples were analysed at quality controlled NATA (National Association of Testing Authorities) registered laboratories. Samples were transported in cooled, insulated containers and were analysed within their appropriate holding times.

The details of the quality assurance program for the major investigation is provided in Appendix C.

4. CONTAMINANTS AND THEIR ASSESSMENT CRITERIA

4.1 INTRODUCTION

This section broadly describes the toxicology of the contaminants detected in the Northbridge redevelopment area and the criteria used to assess that contamination. Criteria exists for the assessment of soil contamination from both an environmental and human health perspective. Criteria used to determine the suitability of material for different classes of landfill are also provided.

These criteria are then applied to the contamination detected which is described in detail in Section 5.

4.2 ENVIRONMENTAL CONTAMINANTS

The potential environmental and health implications associated with contaminants detected at the site are outlined below.

4.2.1 Heavy Metals

Heavy metals are found naturally in the environment in soil, water and the atmosphere in various forms but usually in small quantities. A number of these metals are essential for the healthy function of organisms, however in larger quantities heavy metals can be toxic to humans and other organisms.

Some heavy metals are unable to be metabolised and thus accumulate in organisms during their lifetime, in particular aquatic fauna from polluted environments. Whilst the contaminant may not be toxic in small quantities, organisms at the higher end of the food chain such as fish may accumulate sufficient levels via ingestion of other organisms, for heavy metal toxicity to develop. This is termed bioaccumulation.

The effect of heavy metals on humans varies depending on the form or compound the metal is in. If inhaled, some forms of heavy metals can cause respiratory disease including cancer and bronchitis. Skin contact with particular heavy metal compounds can lead to skin conditions such as dermatitis. Various diseases including brain damage, cancer and organ damage may result from ingestion of certain heavy metals. Lead in particular is linked with decreased IQ values in small children.

4.2.2 Hydrocarbons

The term hydrocarbons encompasses many natural and manufactured organic substances, including liquid and gaseous substances such as oils, volatile spirits and natural gas. Hydrocarbons can cause environmental harm through the chemical and physical nature of the various compounds. Hydrocarbons may be accumulated through the food chain and are often found to be persistent in the environment.

Some hydrocarbons become incorporated into sediments and persist in the environment, others are water soluble and enter the food chain. Bioaccumulation of hydrocarbons just like heavy metals can cause harmful effects to organisms higher up in the food chain.

Inhalation of some forms of volatile hydrocarbons by humans can cause respiratory irritation or affect the nervous system. Some hydrocarbon compounds are carcinogenic and mutagenic.

4.2.3 Pesticides

Some organochlorine compounds (OC) are used as pesticides, and can be extremely toxic to mammals and aquatic organisms. They may be accumulated through the food chain and are often found to be persistent in the environment. Examples of organochlorine pesticides are DDT and dieldrin.

4.2.4 PCBs

Polychlorinated Biphenyls are similar to OC pesticides in structure and have similar chronic effects including persistence in the environment. Acute effects are not as serious as OC pesticides.

4.3 ENVIRONMENTAL ASSESSMENT CRITERIA

Environmental assessment criteria can be effectively divided into two distinct categories:

1. an investigation level, if exceeded, should be used as the basis for further evaluation of the risks to potential receptors which maybe the environment or human health.

2. an action level where concentrations or the bioavailability of the contaminant represents a risk to the environment or human health. Such levels prompt action or a response which will necessitate some form of remediation or management. In terms of a response or clean-up criteria, this value is normally based on a particular landuse and environmental setting.

4.3.1 Soil Contamination

The risks associated with contaminated soil relate to adverse effects on human health and environmental damage to flora and fauna. There is also the potential to impact underlying groundwater.

Human exposure may arise from repeated direct contact over a long period of time with the contaminated soil or vapour emissions, or via consumption of produce grown in such soils. Environmental damage may take the form of phytotoxicity to plants or toxicological effects on soil microorganisms.

The criteria for assessing the need for remediation will be based on maintaining the utility of the land for residential use. This will be achieved by removing contaminated soil which represents a risk to human health.

The contamination status of the remaining surface soils on-site will be assessed for residential suitability using either the DEP endorsed environmental investigation levels which represent no risk to either the environment or human health, or application of a site specific health risk assessment (HRA). The HRA approach is outlined in Section 4.4.

The Department of Environmental Protection (DEP) position on soil contamination is outlined in the public position paper; Contaminated Sites; Assessment and management of contaminated land and groundwater in Western Australia, May 1997 (DEP, 1997).

Key elements of the position paper relevant to this proposal are stated in Position Numbers 3 and 14.

- ***Position No 3*** *: A contaminated site is defined as 'A site at which hazardous substances occur in soil or groundwater at concentrations above background levels and where assessment indicates it poses, or has the potential to pose, an unacceptable risk to human health or the environment'.*

- ***Position No 14*** *: It is proposed to introduce a scheme for defining investigation and remediation levels based on the approach recommended in the ANZECC/NHMRC Guidelines for the Assessment and Management of Contaminated Sites. This scheme consists of two complementary approaches:*

  1. *the first approach involves using generic criteria for the protection of human health and the environment. At present, generic soil investigation criteria will be based on national criteria developed by ANZECC/NHMRC in the Guidelines for the Assessment and Management of Contaminated Sites.*

  2. *the second approach recognises that the effects of contamination vary considerably depending upon site specific factors. Under this approach the generic criteria are used as guidance values to highlight issues of possible concern and trigger the need for further investigation.*

4.3.2 Soil Assessment Criteria

The DEP currently employs the Australian and New Zealand Guidelines for the Assessment of Contaminated Sites (ANZECC/NHMRC 1992) and in their absence for certain chemical compounds, the Dutch Guidelines for Soil Remediation (1983) for the assessment of soil contamination.

The ANZECC guidelines include Environment Investigation Threshold (B) levels and Proposed Health Investigation Level Guidelines for a small number of common contaminants. Where contamination is identified at concentrations in excess of the ANZECC B thresholds, further investigation and evaluation on a site-specific basis may be warranted. A site-specific evaluation would include a consideration of future site use, human health risks and impacts on the nominated beneficial uses.

The ANZECC Health Investigation Level Guidelines apply to arsenic, cadmium, lead and Polycyclic Aromatic Hydrocarbons (PAHs), which are frequently occurring contaminants of significance. These levels have been developed using a health risk assessment approach and can only be applied with reference to particular exposure settings.

Where no Environmental Investigation Threshold is nominated, the use of the Dutch B guidelines is recommended.

The Dutch (The Netherlands Department of Housing, Physical Planning and the Environment) guidelines have been widely used for assessing appropriate levels of contaminants in soils. The guidelines nominate various action levels for a range of contaminants. The Dutch A levels represent a background or reference value. The Dutch B levels represent an investigation threshold, above which further consideration of the impact of contamination or land use is warranted. Contaminant levels below Dutch B are generally considered acceptable for sensitive landuses such as residential.

The Dutch C levels represent a threshold of contamination at which clean-up is likely to be required. Levels below Dutch C are generally considered appropriate for a commercial or industrial land use.

The soil criteria used for assessing the presence of contamination (not necessarily from a human health perspective) at the NRA will be based on the ANZECC B guidelines, and in the absence of relevant ANZECC levels, the 1983 Dutch B criteria. These criteria are for assessment purposes only and are not to be viewed as clean-up or response levels. Response levels or remediation goals are based on a number of factors and are derived for protecting likely receptors be they environmental or human.

A number of potentially hazardous substances were found in the soil at the NRA. The nature and extent of this contamination is described in detail in the following Section 5.

Potentially hazardous substances are usually identified by considering which materials may have been used or stored on a site, or may have arrived through dumping or site filling. The contaminants identified in the NRA are based on the Phase 1 Environmental Site Assessment program which found these contaminants above environmental investigation levels:

- Heavy Metals
  - Cadmium
  - Chromium
  - Copper
  - Lead
  - Zinc

- Hydrocarbons (TPH or Total Petroleum Hydrocarbons: aliphatic)
- Chlorinated Hydrocarbons
  - Organochlorine Pesticides (Dieldrin, DDT & derivatives)
  - Polychlorinated Biphenyls (PCB)

It is noted that neither biologically or physically hazardous materials are an issue with the NRA and that only chemical toxicants are considered.

Table 3 outlines environmental and human health investigation levels used to assess the contaminants of concern identified at the Northbridge redevelopment area.

4.4 HEALTH RISK ASSESSMENT

Health risk assessment (HRA) is commonly used to assess the health impacts associated with contaminated soil. This process allows for the development of site-specific risk-based criteria which can be applied as response levels for remedial works (ie clean-up criteria for remediation or levels requiring management action).

Health risk assessment is a primary component in an overall risk-based approach to decision making which seeks to manage risk to human health and facilitate redevelopment of contaminated land. Determining the level of risk of an adverse effect on human health uses a structured and well-recognised process outlined in the ANZECC Guidelines for the Assessment and Management of Contaminated Sites (1992).

The principal components of this process are:

- hazard identification;
- exposure assessment;
- toxicity evaluation;
- risk characterisation.

The health risk assessment process is illustrated on Figure 5.

An important tenet of health risk assessment is that the underlying objective is to effectively protect the most sensitive individuals in the exposed population (for example children or the elderly). In sufficiently protecting the more sensitive receptor groups in the population it is assumed that the general population is protected.

Health risk assessment seeks to determine the intake of a chemical by an individual and how this level compares to a nominal dose that is considered acceptable. With respect to soil contamination, exposure may be estimated via a range of routes, including ingestion of soil, inhalation of volatiles or particulates, dermal absorption and exposure via the food chain.

In assessing possible adverse effects on human health, consideration is given to a range of carcinogenic and non-carcinogenic effects. It is often the carcinogenic effects that are limiting in terms of possible adverse effects.

The advantage of using a health risk assessment model is that specific criteria can be determined for various land uses such as residential, commercial and public open space. Setting specific criteria for a given land use determines the level of remediation required to achieve protection of human health.

A preliminary HRA has been performed for the Northbridge redevelopment area and is presented as Appendix D. The purpose of this preliminary HRA is to determine whether application of site specific health risk assessments are suitable for the NRA.

4.4.1 Health Based Soil Investigation Levels

The National Environmental Health Forum (NEHF) is a body made up of Directors of Environmental Health from each state and territory and the Commonwealth of Australia.

The NEHF have established health investigation levels (HILs) which nominate residual soil contaminant levels which are acceptable from a human health perspective. These HILs are based on exposure settings ranging from standard residential to industrial. For those particular exposure settings with minimal opportunities for soil access, the greater the level of residual soil contamination that can be tolerated.

The Discussion Paper (July 1998) on the National Environmental Protection Measure (NEPM) for the Assessment of Contaminated Sites propose that the NEHF HILs be used for assessing the need for further site specific investigations in terms of evaluating human health risk.

The HILs have been included as part of the assessment process as they provide an indication of what level of soil contamination constitutes a risk to human health.

TABLE 3
SOIL CRITERIA

All results expressed as milligrams per kilogram.

CONTAMINANT	ANZECC B GUIDELINES	DUTCH B CRITERIA	HEALTH-BASED SOIL INVESTIGATION LEVEL STANDARD RESIDENTIAL "A"	HEALTH-BASED SOIL INVESTIGATION LEVEL HIGH DENSITY RESIDENTIAL "D"
	INVESTIGATION LEVELS			
	ENVIRONMENTAL		HEALTH	
HEAVY METALS				
Cadmium (Cd)	3	5	20	80
Chromium (Cr^{3+})	50	250	120,000	480,000
Copper (Cu)	60	100	1,000	4,000
Lead (Pb)	300	150	300	1,200
Zinc (Zn)	200	500	7,000	28,000
HYDROCARBONS				
Volatile (C_6-C_9)	NC	00	NC	NC
Semi-volatile (C_{10}+)	NC	1000	5,600**	22,400**
CHLORINATED HYDROCARBONS				
PCB	1	1	10	40
Dieldrin	0.2	0.5	10	40
DDT	NC	0.5	200	800

Note : NC = No criteria applicable

**= TPH fraction C_{16}+

4.5 LANDFILL DISPOSAL CRITERIA

This section describes the criteria used to assess the hazard posed by contaminated wastes and soil in terms of disposal of the material to landfill.. The objective of the landfill disposal or waste classification criteria is to ensure that wastes are disposed to appropriately managed landfills so as not to create leachate which may have an unacceptable health or environmental impact. This is achieved by ensuring waste is disposed to a landfill which has been designed to safely accommodate such material.

In Western Australia, waste is disposed in accordance with the requirements of the Department of Environmental Protection 'Landfill Waste Classification and Waste Definitions, 1996' as endorsed by the EPA.

Landfill classification is determined by the level of containment of waste the facility can offer. The higher the class of landfill, the more secure the facility. Contaminated soil is disposed to various classes of landfill dependent upon the severity of the contamination. The higher the class of landfill, the greater the level of contamination in soil it can accommodate.

- Class II Landfill low hazard waste (type 1), Class II wastes.
- Class III Landfill low hazard waste (type 1), Class III wastes.
- Class IV Landfill low hazard waste (type 2).
- Class V Landfill intractable waste only.

Currently in the state there are only two approved Class III and one approved Class V landfill facilities. The Class III facilities are within the metropolitan region at Red Hill and Baldivis, whereas the Class V facility is in the Goldfields region at a location near Mount Walton East. The existing Red Hill Class III landfill site contains a secured Class IV landfill cell which is capable of containing high level contaminated soil.

Low level contaminated soil (Class II) is sometimes suitable for use as a special fill. Special fill can be used in locations such as in road and bridge construction or as a fill material at depth.

Conditions within landfills tend to be acidic due to the decomposition of organic wastes. Such acidity can mobilise toxic components in buried waste material including contaminated soil. This is particularly relevant to heavy metals which can be mobilised in acidic conditions. To assess the leaching potential of such waste, tests known as the Toxicity Characteristic Leaching Procedure (TCLP) which emulate landfill conditions are performed.

To reduce the leachable component of contaminated soils, chemical stabilisation can be undertaken. This reduces the mobility of the contaminant and thus makes it suitable for disposal to landfill.

In order for contaminated soil to be disposed to a landfill facility, the material must satisfy two sets of criteria:

1. Total contaminant concentrations must be below the maximum criteria set for that particular class of landfill, and

2. The leachable fraction extract (TCLP result) must be below the maximum criteria set for that particular class of landfill.

The landfill assessment criteria applicable to the contaminants found on-site are presented on Table 4.

TABLE 4
LANDFILL DISPOSAL CRITERIA

All soil results expressed as milligrams per kilogram.

All TCLP results expressed as milligrams per litre.

CONTAMINANT	CLASS II		CLASS III		CLASS IV		CLASS V	
	SOIL	TCLP	SOIL	TCLP	SOIL	TCLP	SOIL	TCLP
HEAVY METALS								
Cadmium (Cd)	5	0.02	50	0.2	500	2	>500	>2
Chromium (Cr)	250	0.5	2500	5	25000	50	>25000	>50
Copper (Cu)	100	20	1000	200	10000	2000	>10000	>2000
Lead (Pb)	300	0.1	3000	1	30000	10	>30000	>10
Zinc (Zn)	500	50	5000	500	50000	5000	>50000	>5000
HYDROCARBONS								
Volatile TPH (C_6-C_9)	100	NC	1000	NC	10000	NC	>10000	NC
Semi-volatile TPH (C_{10}+)	1000	NC	10000	NC	100000	NC	>100000	NC
ORGANOCHLORINE PESTICDES								
Dieldrin	NC	0.003	NC	0.03	NC	0.3	NC	>0.3
DDT	NC	0.2	NC	2	NC	20	NC	>20
OTHER								
PCB	<2	NC	<50	NC	<50	NC	>50	NC

5. NATURE AND EXTENT OF SOIL CONTAMINATION

5.1 INTRODUCTION

This section sets out the nature and extent of contamination that has been identified over the Northbridge redevelopment area. Soil contamination has been the subject of two detailed investigations in 1997/1998 and 1999 (HGM 1998 and Egis 1999). The first of these studies investigated soil contamination along the tunnel alignment. Soil contamination along either side of the tunnel was investigated in the 1999 study.

Investigations of the soil on the tunnel alignment found elevated levels of lead and zinc above the ANZECC B environmental investigation level. This material was disposed to landfill during the tunnel excavations. Clean fill was used to cover the tunnel which has since been validated as clean during the recent 1999 investigations.

The findings of the earlier tunnel assessment were used to determine the strategy for the 1999 investigation of soils either side of the tunnel alignment. The land on top of the tunnel was cleared of buildings and structures at the time of the soil assessment, whereas the land adjacent to the tunnel is mostly developed. The 1999 sampling strategy was modified to account for the presence of these structures as only readily accessible areas could be investigated. Soil in private residences and beneath hardstand and buildings on government land was not assessed.

The results of the environmental investigations above the tunnel alignment are provided in Section 5.2. Results from investigations along either side of the tunnel alignment are outlined in Section 5.3. A summary is provided in Section 5.4. The findings of the preliminary health risk assessment are summarised in Section 5.5.

5.2 INVESTIGATIONS ALONG TUNNEL ALIGNMENT

A number of environmental issues were required by the Environmental Protection Authority to be addressed by the developers, Bauderstone Clough Joint Venture (BCJV). These included the management of soil contamination resulting from previous landuses within the BCJV tunnel construction areas.

Historical studies on land within the tunnel alignment were undertaken by the Main Roads Department (Rust PPK, 1995) and by BCJV (BCJV, 1996). The studies showed that land within the tunnel construction alignment had a varied history of industrial, commercial and residential landuses. Archival records also indicated that some areas in the tunnel alignment may have been used as liquid waste disposal sites.

A preliminary soil contamination assessment was commissioned by BCJV in 1997 to comply with the EPA requirements. The assessment was undertaken by qualified environmental consultants and considered land within the MRS boundaries for the Northbridge Tunnel development. The assessment report was to provide an appraisal of the contamination and the likelihood of encountering soil contamination during the tunnel construction and associated redevelopment areas.

The BCJV soil contamination assessment was performed in a number of stages relating to the Blocks previously outlined in Section 2.3. Block A was not assessed as no excavation was required. The soil assessment strategy was largely based on the information collected from landuse and historical studies.

A summary of the results and findings of the BCJV soil assessment are provided in Appendix B. Contamination encountered as part of the tunnel construction has been removed off-site and replaced with clean fill.

5.3 INVESTIGATIONS ADJACENT TO TUNNEL

The following is an outline of the assessment of soil contamination on either side of the tunnel, and any limitations regarding the sampling and analytical strategy. Results are presented in Appendix B along with the earlier BCJV investigations of the tunnel alignment.

The purpose of the soil assessment was to identify the nature and distribution of soil contamination on either side of the tunnel alignment. Large areas, particularly in the commercial district of the redevelopment area are covered by hardstand surfaces and buildings. Therefore the contamination status of these soils could not be determined.

5.3.1 Sampling Methodology

Samples were collected at an average density of two sampling locations per typical sized lot (between 0.04 to 0.06 ha in area). The number of sampling locations was increased on a pro-rata basis for larger lots. Samples were not collected from privately owned land.

Soil samples were collected only from locations that were grassed or cleared. Some lots could not be sampled and others sampled at a reduced density. A number of lots were sampled at an increased density, where access was good and interim analytical results showed soil contamination. Soil samples were collected from a total of 307 sampling locations distributed over 9 blocks.

The depth to which soils were sampled was based on the results and findings of the tunnel soil assessment. The tunnel alignment assessment detected contamination primarily in the surface soils to less than 1 m depth. Contamination up to 2 m depth was identified at only two localised areas on Block B.

Based on past and current landuses, and on the tunnel assessment findings, the soil sampling program comprised the collection of composite samples over the following depth intervals:

- surface to 0.5 m,
- 0.5 to 1.0 m, and
- 1.0 to 1.5 m.

In Block B, some samples were collected to 2.0 m depth at locations where contamination greater than 1.5 m depth was identified in soils on the tunnel alignment.

In several locations rubble and rock prevented sample recovery to the target depth of 1.5m, in which case samples were collected up to the maximum achievable depth.

5.3.2 Sample Analysis

All samples collected over the surface to 0.5 metre depth were analysed for the following suite of heavy metals:

- cadmium,
- chromium,
- copper,
- lead,
- nickel, and
- zinc.

In addition to the heavy metal suite, a proportion of samples were analysed for hydrocarbons or pesticides based on field observations or where the previous or current landuse of the lot indicated potential contamination.

Soil from greater depths at each sampling location were only analysed where the surface sample showed concentrations of contaminants above the ANZECC B environmental investigation level or Dutch B criteria in its absence.

5.3.3 Assessment Criteria

All soil samples have been initially screened against the ANZECC B environmental investigation level in accordance with ANZECC Guidelines for the Assessment and Management of Contaminated Sites. This has previously been described in Section 4.

In terms of assessment of risk to human health, the 1998 National Environmental Health Forum Health-based soil investigation levels have been applied. This was considered the principal receptor group as there are no nearby sensitive environmental receptors such as wetlands.

All contaminant levels above the environmental investigation levels (ANZECC B) have been subject to the preliminary health risk assessment. The findings of this health risk assessment are detailed in Section 5.5.

5.4 SUMMARY OF NORTHBRIDGE SOIL CONTAMINATION

Table 5 provides a summary of the soil contamination detected in the Northbridge redevelopment area in excess of the environmental investigation level.

Table 6 provides a summary of the soil contamination detected in the Northbridge redevelopment area from a human health perspective that exceeds the lower density standard residential NEHF HIL.

Figures 6A to 6I show the blocks in the redevelopment area where soil contaminant concentrations are below ANZECC B guidelines (environmental levels) which represents uncontaminated land suitable for immediate redevelopment. Soil above the tunnel alignment has been validated as below ANZECC B guidelines and is therefore included. Soil sampling locations and the contaminants identified above the ANZECC B guidelines are also shown on the figures.

Figures 7A to 7I show the locations in the redevelopment area where soil contaminant concentrations are below both the ANZECC B guidelines and the NEHF HIL for a standard residential setting. The only contaminant exceeding the health investigation level is lead (the standard HIL for lead is the same as ANZECC B). Sampling locations, and locations where lead concentrations exceed health investigation levels are shown on the figures.

TABLE 5
SUMMARY OF SOIL CONTAMINATION

In excess of Environmental Investigation Levels

Location (Block)	Contaminants	ANZECC B Environmental Investigation Level (mg/kg)	Maximum Contaminant Concentration (mg/kg)
A	None above guidelines		
B	Copper	60	250
	Lead	300	3400
	Zinc	200	950
	Dieldrin	0.2	0.5
	TPH	100	820
C	Copper	60	130
	Lead	300	630
	Zinc	200	880
	PCBs	1	5
D	Copper	60	220
	Zinc	200	2100
E	Copper	60	510
	Lead	300	780
	Zinc	200	670
F	Cadmium	3	3.7
	Chromium	50	100
	Copper	60	150
	Lead	300	3000
	Zinc	200	1500
	Dieldrin	0.2	0.5
G	None above guidelines		
H	Chromium	50	53
	Copper	60	73
	Lead	300	430
	Zinc	200	5500
	TPH	100	12500
I	Copper	60	270
	Lead	300	1000
	Zinc	200	1000
	Dieldrin	0.2	1.3

5.5 FINDINGS OF PRELIMINARY HEALTH RISK ASSESSMENT

The preliminary health risk assessment (HRA) reviewed all the contaminants detected above the ANZECC B environmental investigation level and evaluated the risk of these contaminants to human health. The health risk assessment approach is detailed as follows with the HRA report attached as Appendix D.

The HRA assessed the contaminants against the generic 1998 NEHF health investigation levels (HIL). An appropriate exposure setting was selected based on the proposal for high density residential development, maximum contaminant levels in each block were compared to this Tier 1 criteria. Maximum contaminant levels were assessed rather than averages due to the size of the project area and the density of the soil sampling.

This screening of maximum contaminant levels identified only lead and volatile and heavy fraction hydrocarbons as potential health issues. Heavy fraction hydrocarbon contamination exceeded the most sensitive standard residential exposure setting but not the high density residential setting. Exceedence of the HIL Tier 1 criteria was found to occur only on Blocks B and F. The magnitude of exceedence was less than 3 times the health criteria for lead and approximately 8 times for the volatile hydrocarbons.

A site specific or Tier 2 risk assessment was then applied to lead and volatile hydrocarbons. Both contaminants are considered to be non-carcinogenic (ie toxic but does not cause cancer). The risk assessment therefore focused on identifying the exposure pathways and the likelihood of adverse heath effects arising from exposure to these contaminants.

Lead requires application of biokinetic modelling to determine safe blood lead levels in children. Such modelling is beyond the scope of most risk assessment projects. As a consequence, the NEHF derived lead level was considered to be an appropriate conservative health based investigation level for the NRA.

The NEHF has not set any HILs for volatile hydrocarbons due to complex environmental behaviour pathways and carcinogenicity issues. A risk assessment computer model was used to evaluate residual contamination which found it to be acceptable from a human health perspective.

The preliminary health risk assessment of the NRA has identified lead to be the most significant contaminant in terms of human health. The other contaminants above ANZECC B guidelines but below the NEHF HIL have not been considered in terms of a site specific health risk assessment.

The findings of the preliminary health risk assessment do suggest however that a site specific assessment of the other contaminants will confirm the level of contamination does not pose a risk to human health.

TABLE 6

SUMMARY OF SOIL CONTAMINATION

In excess of NEHF Health Investigation Levels

Location (Block)	Contaminants	Health Investigation Level		Maximum Contaminant Concentration (mg/kg)
		Standard Residential	High Density Residential	
A	None above guidelines			
B	Lead	300	1200	3400
	TPH	NC	NC	820
C	Lead	300	1200	630
D	None above guidelines			
E	Lead	300	1200	780
F	Lead	300	1200	3000
G	None above guidelines			
H	Lead	300	1200	430
	TPH	5600	22400	12500
I	Lead	300	1200	1000

6. APPROACH TO ENVIRONMENTAL MANAGEMENT

6.1 INTRODUCTION

This section describes the available remediation options for rehabilitating the Northbridge redevelopment area to a condition suitable for residential purposes. The remainder of this section identifies the general requirements that the remediation strategy needs to meet. Section 6.2 outlines the proposed remediation approach with the remedial works outlined in Section 6.3 and transportation in Section 6.4. The EPA's preferred strategies for remediation are set out in Section 6.5. Potential remediation options are summarised in Section 6.6.

6.2 PROPOSED APPROACH

The proposed approach to soil management which best satisfies the project objectives is removal or long term management of contaminated soil in excess of the ANZECC Environmental Investigation Threshold (B) level.

The proposed approach is as follows :

- undertake additional environmental investigations in areas not tested sufficiently during initial investigations;
- determine the proposed landuse status of the contaminated location (ie high density residential, open space or standard residential) and assess contaminant levels against ANZECC B or undertake a site specific health based risk assessment;
- perform a health based risk assessment to the satisfaction of the DEP in locations where contaminant levels above ANZECC B are to be retained. Any such locations will have memorials placed on the Titles;
- remove contaminant concentrations above the proposed health based response level be it ANZECC B or health based criteria;
- a Contaminated Site Schedule (CSS) will be created identifying the investigation status and level of any contamination detected on all lots which have not been remediated prior to sale by the proponent . Lots which have been investigated and found to contain contaminant levels below the ANZECC B level or have been remediated will not be placed on the schedule.

- A lot will remain on the CSS until it has been remediated to ANZECC B or investigated including any subsequent remediation in the case of an unassessed lot. Sites subject to a health based risk assessment will remain permanently on the CSS which will provide a trigger for reassessment in the event of future rezoning.

Figure 8 summarises the management strategy. Figures 9A to 9I identify sites that requires management and land which may be developed without further environmental investigations.

Locations which require further investigations will be assessed for contaminants as per the initial site assessment.

6.3 REMEDIAL WORKS

Validation of soil remediation will involve the analytical testing of remaining soils following excavation of the contaminated soil. This will be compared with the response or clean-up levels to demonstrate compliance.

The proposed approach to validation of remedial works is :

- contaminated soils will be segregated and disposed to the appropriate class of landfill;

- contaminated soil destined for disposal to landfill will be assessed in accordance with the requirements of the Department of Environmental Protection 'Landfill Waste Classification and Waste Definitions, 1996';

- soil disturbed to access contaminated soil, but which itself has levels of contaminants which satisfy the definition of 'clean soil' as distinct from the response level, once validated, can be used elsewhere across the site: and

- reinstate the excavations with fill sourced either on or off-site and which is certified as 'clean'.

"Clean fill" as distinct from the response level for assessing insitu soil (in the case of HRA derived criteria) is defined as soil containing levels of contaminants which do not exceed the clean fill criteria nominated in the Department of Environmental Protection 'Landfill Waste Classification and Waste Definitions, 1996'; Amendment 1 of 1998.

The location will be considered to be 'decontaminated' or remediated when the soil contaminant concentrations in the validation samples are below the response level. The response levels will either be ANZECC B or a derived health based risk assessment level.

Validation samples will be tested for those contaminants identified during the Phase 1 ESA exceeding ANZECC B environmental investigation level. This will confirm the absence of other possible contaminants in addition to the identified compound requiring remediation.

The frequency of validation sampling will be performed in accordance with a recognised statistically based approach. Such an approach to validation sampling of excavations and stockpiles is outlined in the NSW Environmental Protection Authority Contaminated Sites Sampling Design Guidelines, September 1995. In order to provide final environmental clearance, a Record of Remedial Works (RRW) incorporating validation sampling results will be issued to the Contaminated Sites Branch of the Department of Environmental Protection.

The RRW report will demonstrate compliance to the commitments made by the proponent and will include a description of the remedial works, field observations including a pictorial record, results of validation sampling, quantities and classification of contaminated soil including disposal records.

6.4 TRANSPORTATION OF WASTE

Contaminated soil, although hazardous, is not considered to be a dangerous good. Nevertheless trucks and drivers will operate according to best practice and will be required to transport contaminated in a safe manner with no spillage.

Truck drivers will also be required to comply with an Occupational Health and Safety (OHS) Plan developed specifically for the remediation project.

The details of handling and shipment of contaminated soil are described in Section 7.

6.5 CONTAMINATED SITES POLICY

This section outlines current government policy on the management of contaminated sites in Western Australia and sets the background for reviewing remediation options. The EPA's position on the approach to site remediation is outlined in detail in Interim Policy No 17; 'A Site Remediation Hierarchy for Contaminated Sites, July 1997', and in the DEP public position paper; Assessment and management of contaminated land and groundwater in Western Australia, May 1997 (Position No 13).

The following guidelines are used by the EPA during the assessment of any proposal relating to the remediation of a contaminated site:

- *contaminated soil will preferably be either treated on-site and the contaminants reduced to acceptable levels or be treated off-site and returned for reuse after the contaminants have been reduced to acceptable levels;*
- *the EPA prefers proponents to seek other options rather than either disposal to an approved landfill or the implementation of 'cap and contain' isolation measures. These options will only be considered if treatment of the contaminated material is not practicable, and will need to be undertaken in an environmentally acceptable manner; and*
- *remediation should be undertaken in accordance with the best advice about available techniques and options.*

6.6 SUMMARY OF REMEDIATION OPTIONS

Based on a review of the potential options available to remediate the NRA, the following remediation options were considered viable from a technical, effectiveness and cost perspective. The potential remediation options are:

1. Do nothing.
2. On site treatment and containment.
3. Removal to a suitable landfill with or without pretreatment.

The soil contamination identified at the NRA requiring remedial action consists of heavy metals and hydrocarbons. The viable remediation options for these contaminants are evaluated in the following subsections.

A review of remediation outlined in the following subsections considers landfill disposal to be the most appropriate remediation option for the contaminated soil identified at the NRA given the nature and volume of material.

6.6.1 Stabilisation/Solidification

Chemicals can be applied to the soil to reduce the availability of the contaminant to the environment. Chemical fixation utilises cementing agents such as Portland cement, fly ash, quick lime or limestone, blast furnace slag and other forms of activated silica which bind the contaminants (especially heavy metals) to the soil particles.

Treatment by chemical stabilisation techniques in particular polymerisation can be expensive and is generally suitable for high levels of contamination which were not detected at the NRA. To improve the suitability of heavy metal contaminated soil for disposal at landfill, such techniques are sometimes employed.

6.6.2 Soil Washing

Extractant solvents such as water, surfactants and acids are flushed through the contaminated material, either in-situ or ex-situ, to remove the contaminants from the soil.

Soil washing is expensive but is effective in removing both organic and inorganic compounds from reasonably permeable soils. However, soil washing is generally only viable for large volumes of soil which does not apply to the NRA.

6.6.3 Incineration and Thermal Treatment

Heat is used to destroy organic and some inorganic compounds. Incineration relies on very high temperatures whereas thermal treatments utilise lower temperatures, pyrolysis and high pressure.

These processes are ideally suited for organic compounds such as hydrocarbons and pesticides. The technology is relatively expensive and generally only used for intractable wastes. Heavy metals such as the lead found in the NRA are not destroyed in the process.

Soils can be treated by low rate injection into cement kilns or a purpose built burner to supplement energy needs. Air emissions may be an issue with such a destruction method. The volume and level of hydrocarbon contaminated soil detected in the NRA does not warrant such an approach.

6.6.4 Bioremediation

Bioremediation relies on the ability of microbial organisms to break down contaminants into harmless byproducts. This can be achieved either in or ex-situ, however the latter is generally considered more effective.

Bioremediation is ideally suited to organic compounds such as the hydrocarbons found in the NRA. They can also be utilised to convert some heavy metal compounds into less toxic forms. However, most heavy metals will actually adversely affect the process of bioremediation.

A time period is involved in bioremediating organic contaminants, especially with regard to stable non-volatile compounds. In addition to the time involved, a large area of land needs to be dedicated for the process.

Bioremediation projects performed within WA indicate that high concentrations of heavy fraction oils are in some cases uneconomical to bioremediate. Bioremediation of wastes with a lower composition of heavier oils has been successful. The volume and level of hydrocarbon contaminated soil detected in the NRA does not warrant such an approach.

6.6.5 Landfill Disposal

This approach is cost effective compared with the technological approaches described above. The removal of contaminated soil ensures sites are cleaned up to stringent standards with no future potential liabilities. However, disposing of contaminated soil to landfill places pressure on the capacity of these facilities.

Some contaminants such as heavy metals are better suited to landfill disposal as they cannot be treated easily compared to organic compounds which can potentially be bioremediated (the most common approach in WA for remediating hydrocarbon compounds).

Dependent upon the severity of the contamination, the soil is disposed to various classes of landfill ranging from inert to putrescible to intractable. Soil with very low levels of contamination maybe able to be used as special purpose fill for road construction or in deep excavations.

Managed landfill disposal offers a reliable and secure approach to dealing with contaminants that have the potential to persist in the environment.

6.6.6 Other

Other remedial options which were evaluated but are considered unsuitable or too expensive are soil fractionation, vitrification and the Ecologic Process.

7. ENVIRONMENTAL MANAGEMENT DURING REMEDIATION

7.1 INTRODUCTION

During the remediation of the site, a number of environmental and social impacts could potentially arise which require management. This section describes in detail the management of these issues ranging from dust control to transport of the contaminated soil. Relevant social impacts relate to increased vehicle traffic to public and worker safety. The issues requiring management are identified as:

- dust and noise emissions;
- vibration from machinery;
- handling and transport of contaminated soil;
- stabilisation of earthworks related to clean-up;
- control of surface runoff;
- increased vehicle traffic;
- public and worker safety; and
- site security.

7.2 DUST

The operations of trucks and earthmoving equipment have the potential to generate contaminated and nuisance dust.

Management of dust from contaminated areas subject to earthmoving activities and from contaminated stockpiles is an important environmental consideration, as there is the possibility of contaminated material being inadvertently spread from uncontrolled airborne dust emissions. The proposed remediation program will be managed to prevent such dust emissions from occurring.

Trucks and roads will be wetted down where necessary and sprinklers will be employed to minimise dust generation in working areas.

The contractor will be required to comply with the Department of Environmental Protection's Land Development Sites and Impacts on Air Quality, a guideline for the prevention of dust and smoke pollution from land development sites in Western Australia, 1996 and Interim Policy No 18; 'Air Quality Impacts from Development Sites', July 1997'. The acceptable limit for total dust concentration in the atmosphere is 1,000 ug/m^3 measured over a 15-minute time period.

The following actions may also be undertaken to manage dust generation:

- in dry conditions; access tracks, roads, stockpiles and operational areas will be kept damp with the use of water trucks. This will be especially applicable to contaminated areas. A water truck will be available throughout the remediation phase;
- where considered necessary, wind fencing will be placed around the periphery of contaminated areas undergoing excavation;
- disturbed areas will be stabilised with hydromulching or equivalent if necessary, to prevent dust generation;
- monitoring of nuisance dust;
- a vehicle wash down pond will be provided on the exit route from the site to remove any contaminated soil adhering to transport vehicles;
- all machinery used in contaminated zones will be thoroughly cleaned by high pressure water spray or equivalent prior to leaving that location to prevent the spread of contaminated material. Any residual material captured from cleaning the machinery during washdown will be disposed of appropriately.

7.3 NOISE

Noise will be generated by earthmoving machinery and trucks moving to and from the site. The area is already subject to a relatively high level of background noise from busy roads and tunnelling activities.

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

- machinery will generally operate only during daylight hours between 0700 and 1800 hours Monday through to Saturday;

- all equipment including trucks will be in good working order with effective silencers; and
- occupational noise exposure will be in compliance with Worksafe WA requirements thus limiting the potential for off-site impacts.

7.4 VIBRATION

Vibration will be generated by earthmoving machinery, trucks and compaction equipment associated with reinstatement of remediation areas. Contractors will be obliged to take every reasonable effort to minimise vibration.

The temporary presence of excavators and trucks is a common practice within residential areas. Vibration is not expected to be a significant issue in the remediation process.

In order to control vibration and reduce or eliminate possible complaints or damages claims, the contractor will be required to comply with the requirements of *AS 2670.2 - Evaluation of Human Exposure to Whole Body Vibration.*

7.5 SURFACE RUNOFF

Remediation of the site will be managed to prevent or minimise stormwater runoff from entering areas of exposed contaminated soil. Due to the high infiltration capacity of the natural ground, runoff is unlikely to be generated. However, should runoff become an issue, appropriate drainage control measures will be implemented.

7.6 CONTAMINATED SOIL TRANSPORT

All contaminated material will be transported in accordance with best working practices to prevent accidental spillage and so minimise the risk to human health and the environment. The management of transporting contaminated soil is outlined as follows:

- a record of the contaminant characteristics for all soil transported from the site will be kept in a Contaminated Soil Transport Register (CSTR). This will ensure that the soil is disposed to the appropriate class of landfill;

- all contaminated soil will be subject to a consignment system that allows the tracing of all loads from the site to ensure all material reaches the appropriate destination. The practice of consigning loads will allow for a record of the fate of all materials removed from the site, this will be supplied to the site superintendent as required;

- under no circumstances should any material be able escape from the transport vehicles; therefore contaminated material will be transported in covered, properly sealed trucks;

- all trucks will be underloaded and well within the volume and weight capacity for that vehicle to limit the potential for accidental spillage on route;

- trucks will be inspected prior to departure to ensure cover and tailgates are secured;

- a road sweeper will be used on a regular basis to clean public roads in the immediate vicinity of the site; and

- an emergency response plan will be drafted for dealing with accidental spillage on route which will include; basic spill containment equipment on all trucks and chains of command including contact names and telephone numbers for clean-up crews and the emergency authorities. The hazard potential of the contaminated soil will be known to the emergency response team via the CSTR. The remediation contractor will be responsible for the clean-up of all spills.

7.7 TRANSPORT ROUTE

The contaminated material will be transported to the appropriate class of landfill. The actual landfill sites have not yet been determined and will be subject to a tender process which will be performed prior to remedial works commencing. Most of the contamination is Class II material which can be disposed at a number of metropolitan landfill facilities.

Given that the Northbridge Tunnel alignment is in the central part of the city, trucks will gain immediate access to major roads. There will be no traffic along quiet residential streets.

Trucking associated with the remedial works will have a minimal impact on the local traffic network. Truck operators will be required to comply with the Road Traffic Act (1974).

7.8 PUBLIC AND WORKER SAFETY

The proposed remedial works will involve the excavation and handling of contaminated soil which may contain significant levels of lead or possibly other contaminants. Owing to the nature and level of the contamination, there exists the possibility for adverse health effects in unprotected personnel excavating or working in close proximity to such material.

Heavy machinery will be working on the site with transportation trucks entering and leaving during the remedial works. Vehicle traffic also presents an operational hazard to site personnel.

Safe working practices will ensure that the health of site workers and the public are protected. Contractors performing the remedial works will be required to prepare an Occupational Health and Safety (OHS) plan which will be forwarded to Worksafe WA and the DEP for their review and advice prior to commencement of remedial works. The purpose of the OHS plan is to indicate the monitoring and safety requirements for handling contaminated materials. Remedial work that involves the disturbance of contaminated materials will not be allowed until such time as the OHS Plan has been approved by the project superintendent who represents the proponent on-site.

The main method of ensuring the health and safety of the public and site personnel will be to protect against possible exposure to contaminated materials.

The degree of protection required is determined by knowledge of:

1. contamination levels;

2. effects from exposure to these contaminants; and

3. level of risk associated with exposure to the contaminants.

In order to protect the public and site personnel, the elimination or limitation of potential exposure pathways is required. This will be achieved using health and safety measures outlined in the following sections. The soil contamination has been subject to a health risk assessment which has identified exposure pathways and defined the potential level of risk posed by the material.

7.8.1 Worker Health and Safety Measures

In addition to toxicity hazards associated with the contaminated soil, necessary precautions will need to be taken with regard to the following physical hazards:

- operation of heavy plant equipment including excavators, pumps, etc;
- working near deep excavations;
- overhead power lines;
- underground services (including gas and electricity); and
- handling of excavated materials particularly any heavy buried structures or buried pipes that may be encountered.

The safety of all personnel on site will be the responsibility of the contractor, as previously mentioned, will be required to develop and implement an OHS plan. To ensure that remedial works are undertaken safely and in the manner outlined in this remediation plan - a Project Health and Safety Officer (PHSO) shall be appointed. The PHSO will have the authority to direct work, including stoppages, as and when contaminated material is encountered.

The following necessary health and safety measures will be applied according to the nature of the contaminated soil being handled and the particular tasks being undertaken with regard to that material. The actual measures which are implemented will be determined by the PHSO in consultation with Worksafe WA and the DEP. The proposed health and safety measures are:

- Education and training prior to any remedial works to ensure that all personnel are aware of the nature of the materials on-site, the exposure risks, exposure routes, and the precautions to minimise both on-site and off-site exposure, and the risks associated with transporting contaminated soil off-site.
- Site safety will be supervised by the PHSO who will be permanently on-site during remedial works to provide advice and undertake any necessary soil sampling or dust monitoring.
- Responsibility and management of personal health and safety will be clearly defined for all personnel working on-site.
- Areas known to contain contamination will be clearly identified as "contamination zones". Only authorised personnel will work in contamination zones, and only under supervision wearing the appropriate safety equipment.

- Personnel and all site visitors will be required to wear at a minimum; protection comprising hard hats and safety boots. Site personnel working in contaminated zones may in addition need to wear overalls, gloves, safety glasses and/or goggles/face visor.

- Operators of mobile plant and equipment will be required to keep doors and windows closed and remain in the cab at all times whilst in contaminated zones.

- On leaving contamination zones, personnel will be required to change in a decontamination area. All protective clothing will be placed in the decontamination area for disposal and/or cleaning.

- An emergency shower and eye wash point will be provided on-site in case of emergencies.

- A complete first aid kit fully complying with regulatory requirements will be available on-site at all times.

- Communication equipment eg, portable telephones will be made available at all times for use in an emergency situation.

- Eating, drinking, smoking and application of sunscreens and cosmetics will be restricted to designated areas.

- Separate eating and ablution facilities will be provided in areas away from the contaminated zones.

- An emergency response plan will be drafted which will include chains of command including contact names and telephone numbers, and a detailed emergency response to potential events including site evacuation.

7.8.2 Public Safety Measures

To prevent possible direct exposure of hazardous materials to the public, access to the areas undergoing remediation will be restricted. This will primarily be achieved through the provision of perimeter fencing or barrier mesh and placement of warning signs outlining the potential danger. Security patrols will be utilised outside of working hours.

7.9 ENVIRONMENTAL SUPERVISION

To ensure that remedial works are performed to best practice and undertaken according to the approach outlined in this ER, the remediation of the site will be carried out under the guidance of an Environmental Supervisor (superintendent could have dual role) who is independent of the contractor responsible for the remedial works. The presence of an Environmental Supervisor will be dictated by the works in progress, and it is not expected that the position will be required at all times.

The Environmental Supervisor will be a representative of the proponent and have the authority to dictate works directly or through the site superintendent, including any necessary stoppages for environmental reasons, as and when the situation requires.

The tasks for the Environmental Supervisor will be as follows:

- Review the CSTR records for all waste consignment to ensure compliance with the disposal requirements.
- Regularly inspect all plant and equipment working in contaminated areas to ensure adequate cleaning prior to movement out of contamination zones in order to prevent transfer of contaminants to clean areas.

8. MANAGEMENT COMMITMENTS

The Western Planning Commission (WAPC – the proponent) is committed to ensuring that the remediation of the Northbridge redevelopment area is performed in an environmentally responsible manner, and makes the following commitments:

1. The WAPC will undertake soil sampling is to assess the nature and extent of contamination at those locations which do not currently meet the ANZECC B Environmental Investigation Threshold in order to delineate the full extent in locations not yet assessed. This will be performed to the requirements of the Contaminated Sites Branch of the Department of Environmental Protection prior to any remedial works commencing.

2. The WAPC will undertake a site specific health risk assessment to the satisfaction of the Department of Environmental Protection on all contaminants where clean-up to ANZECC B Environmental Investigation Threshold is not proposed. Any such sites will have memorials placed on the Title and will remain on the proposed Contaminated Site Schedule.

3. A Contaminated Site Schedule (CSS) will be maintained which describes those lots to be sold by the proponent with soil contaminants in excess of the ANZECC B Environmental Investigation Threshold.

4. The removal of all contaminated material from the Northbridge redevelopment area in accordance with the management techniques described in this Environmental Review.

5. All contaminated material transported from the site will be carried in appropriately equipped and labelled trucks in a manner consistent with any relevant codes that relate to the transport of the material. This will be performed in a manner consistent with the ADG Code (Australian Code for the transport of Dangerous Goods by road and rail) which is administered by the Department of Minerals and Energy.

6. The ultimate destination of all waste materials will be selected on the basis of waste acceptance criteria set by the Department of Environmental Protection.

7. Dust discharges from the site will be kept within the relevant criteria set by the Department of Environmental Protection guidelines for: Land Development Sites and Impacts on Air Quality Guidelines, 1996.

8. Vibration from the site will comply with the requirements of Australian Standard AS 2670.2.

9. A Record of Remedial Works (RRW) outlining remedial works and validation sampling (inclusive of analytical results) will be performed to confirm site remediation has been achieved. This report will be provided to the Contaminated Sites Branch of the Department of Environmental Protection on completion of remedial works.

10. A report will be prepared by the proponent at the completion of the remediation phase which will provide evidence of conformance to the commitments and Ministerial Conditions set for the project. This report will be provided to the Department of Environmental Protection.

9. REFERENCES

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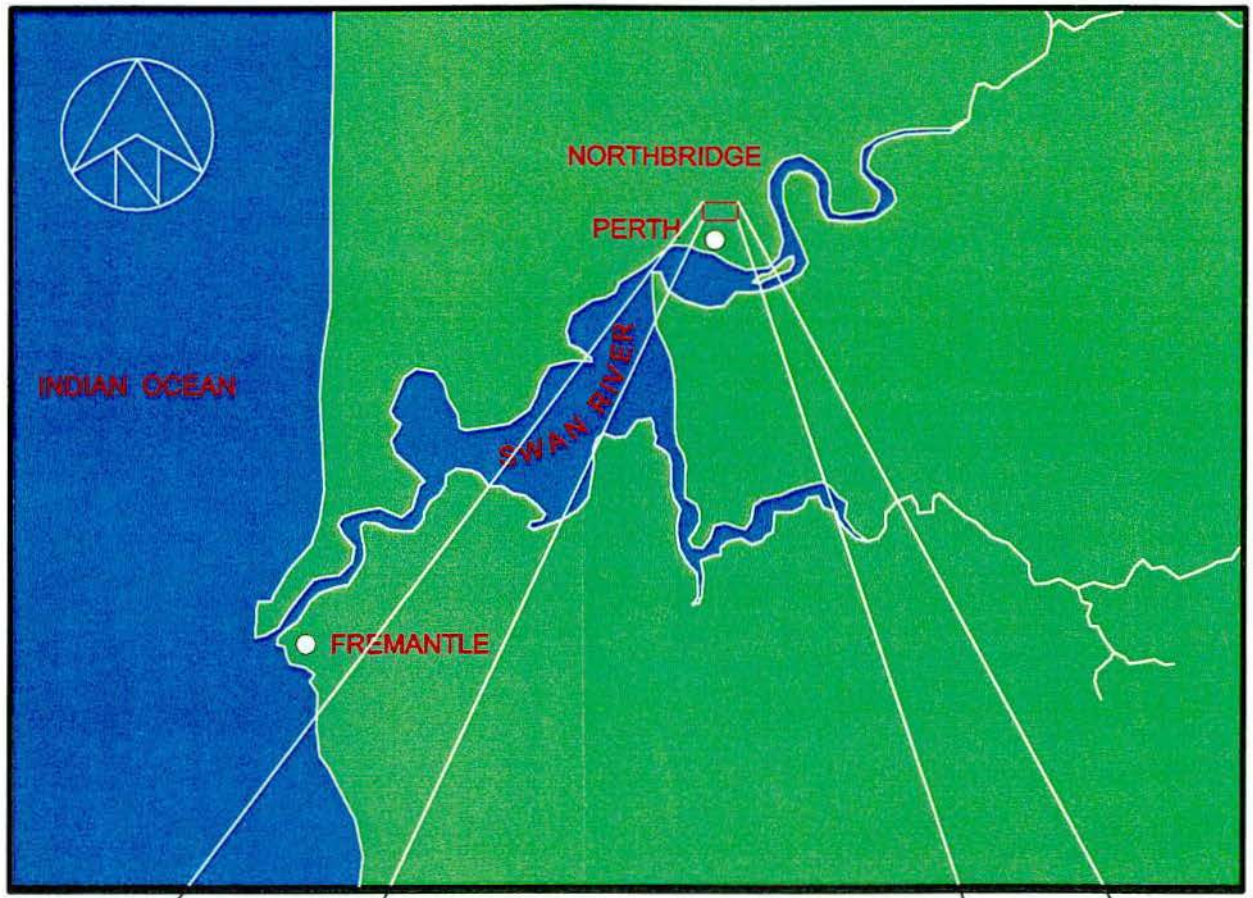
10. ABBREVATIONS

ADG	Australian Dangerous Goods
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
BCJV	Baulderstone Clough Joint Venture
CSS	Contaminated Site Schedule
CSTR	Contaminated Soil Transport Register
DEP	Department of Environmental Protection
DME	Department of Minerals and Energy
EPA	Environmental Protection Authority
ER	Environmental Review
ESA	Environmental Site Assessment
GSWA	Geological Survey Western Australia
HIL	Health Investigation Level
HGM	Halpern Glick Maunsell
HRA	Health Risk Assessment
IWDF	Intractable Waste Disposal Facility
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
MRS	Metropolitan Region Scheme
MRWA	Main Roads Western Australia

OC	Organochlorines
OHS	Occupational Health and Safety
PCB	Polychlorinated Biphenyls
PHSO	Project Health and Safety Officer
RRW	Record of Remedial Works
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total Petroleum Hydrocarbons
WAPC	Western Australian Planning Commission

FIGURES :

1. Assessment Process for Non-Substantial Amendment
2. Locality Map
3. Subdivision Plan(s)
4. Landuse Map
5. Health Risk Assessment Process
6. Soil Contamination - Below ANZECC guidelines
7. Soil Contamination - Below Health Investigation Levels
8. Soil Contamination Management Strategy
9. Management Strategy (Locations Requiring Management)



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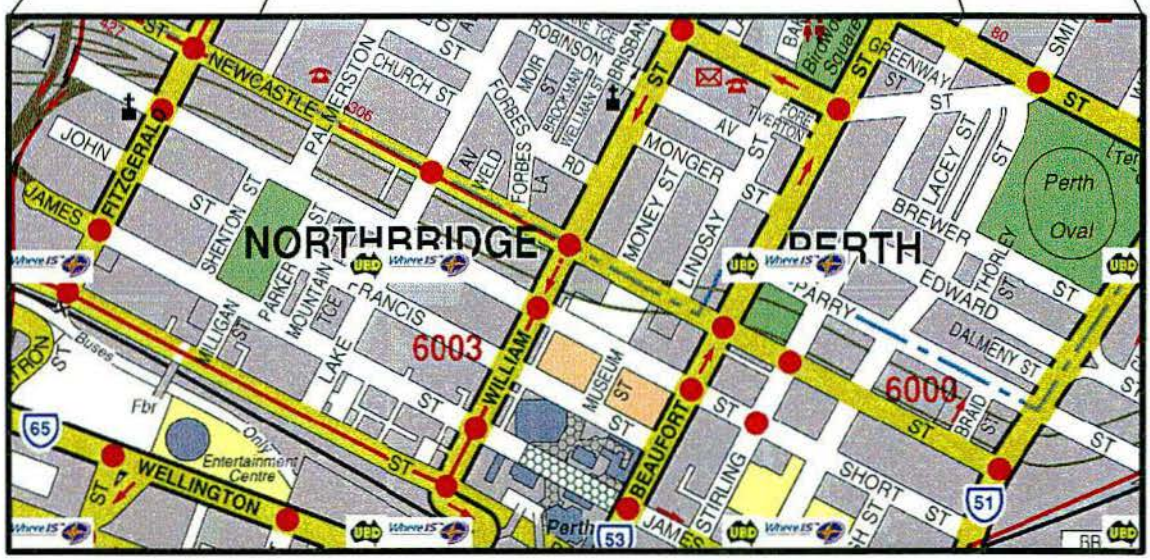

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TITLE

NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION LOCATION PLANS

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A4	VW1216	FIGURE 002	OF	A

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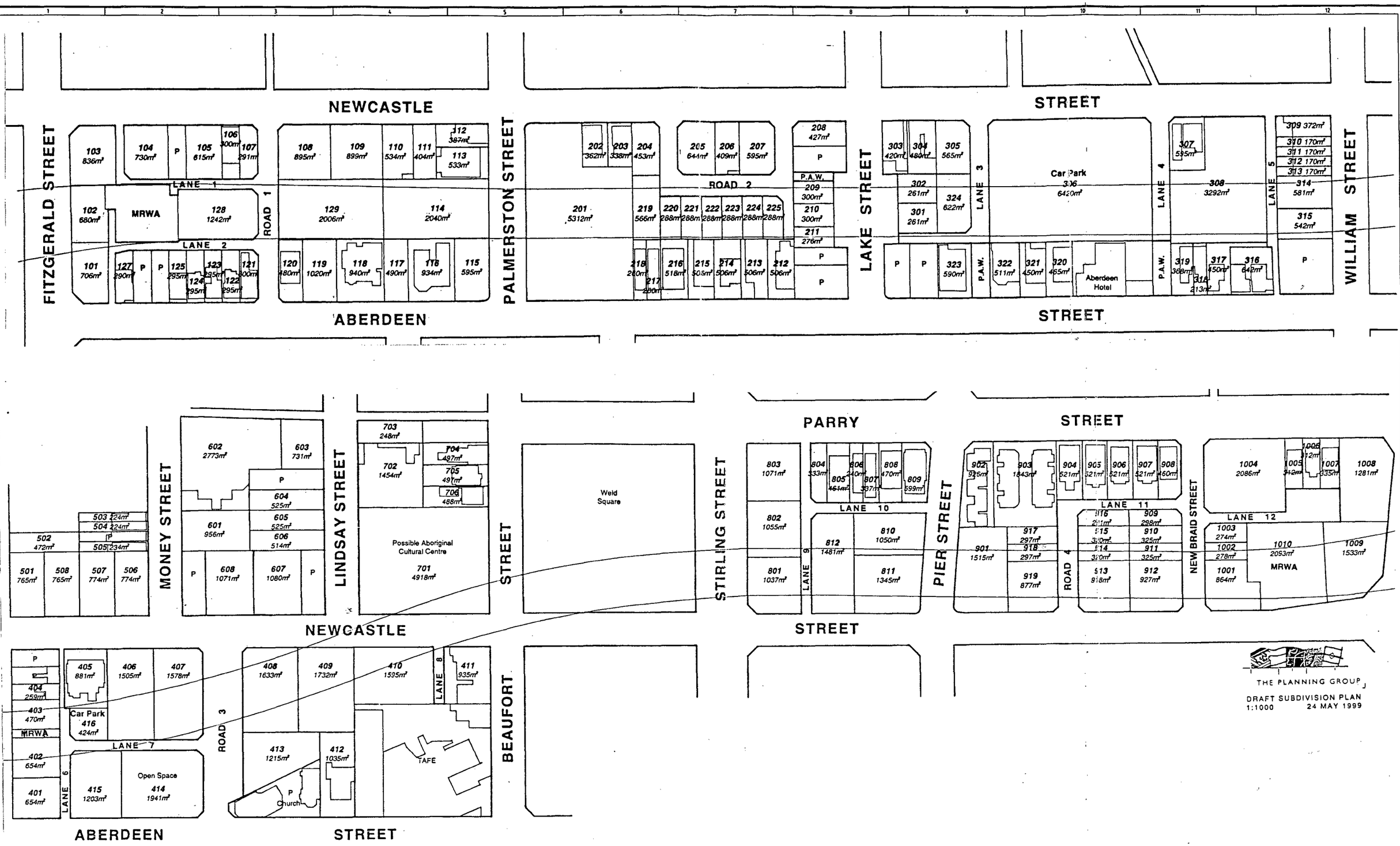

THE PLANNING GROUP

DRAFT SUBDIVISION PLAN
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TITLE
NORTHBRIDGE URBAN RENEWAL
PROPOSED SUBDIVISION PLANS

SIZE	PROJECT No	DRAWING No	SHEET No	REV
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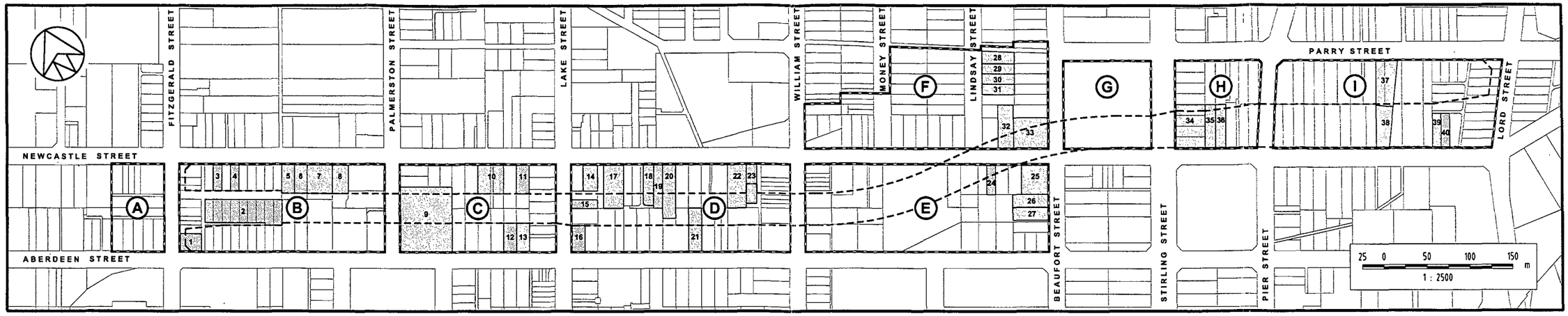

1 METAL MERCHANT
2 GALVANISING FACTORY
3 AUTO BUSINESS
4 PEST CONTROL FACTORY
5 RADIATOR FACTORY
6 SPRAY PAINTER
7 AUTO BUSINESS
8 AUTO BUSINESS
9 METAL FABRICATION
10 VEHICLE SERVICING
11 DRIVING SCHOOL
12 ELECTRICAL BUSINESS
13 METAL FABRICATION
14 AUTO BUSINESS
15 BITUMEN PRODUCTS
16 BAKERY
17 FACTORY
18 SPRAY PAINTING
19 MOTOR BODY BUILDING WORKS AND REPAIR SHOP / DEPOT FOR DRY CLEANING
20 FURNITURE FACTORY
21 AUTO BUSINESS / FURNITURE
22 AUTO BUSINESS
23 FURNITURE FACTORY
24 AUTO BUSINESS
25 FISH CLEANING / WINE SALOON / LEAD LIGHT MANUFATURER / BRICK CLEANING
26 SHOP
27 FURNITURE STORE / DRY CLEANING
28 BAKERY / FLOUR MILL
29 FLOUR MILL
30 FLOUR MILL
31 FLOUR MILL / PLASTIC MOULDING
32 GALVANISING SHOP
33 FURNITURE STORE
34 CAR YARD
35 CAR HIRE AND REPAIR
36 CAR YARD
37 WAREHOUSE
38 AUTO BUSINESS / FACTORY / BRICK CLEANING
39 STAINED GLASS AND LEAD LIGHTS
40 FACTORY / FURNITURE RESTORATION SHOP

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TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
CONTAMINATED LAND USE

SIZE	PROJECT No	DRAWING No	SHEET No	REV
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Figure 5 Health Risk Assessment Process

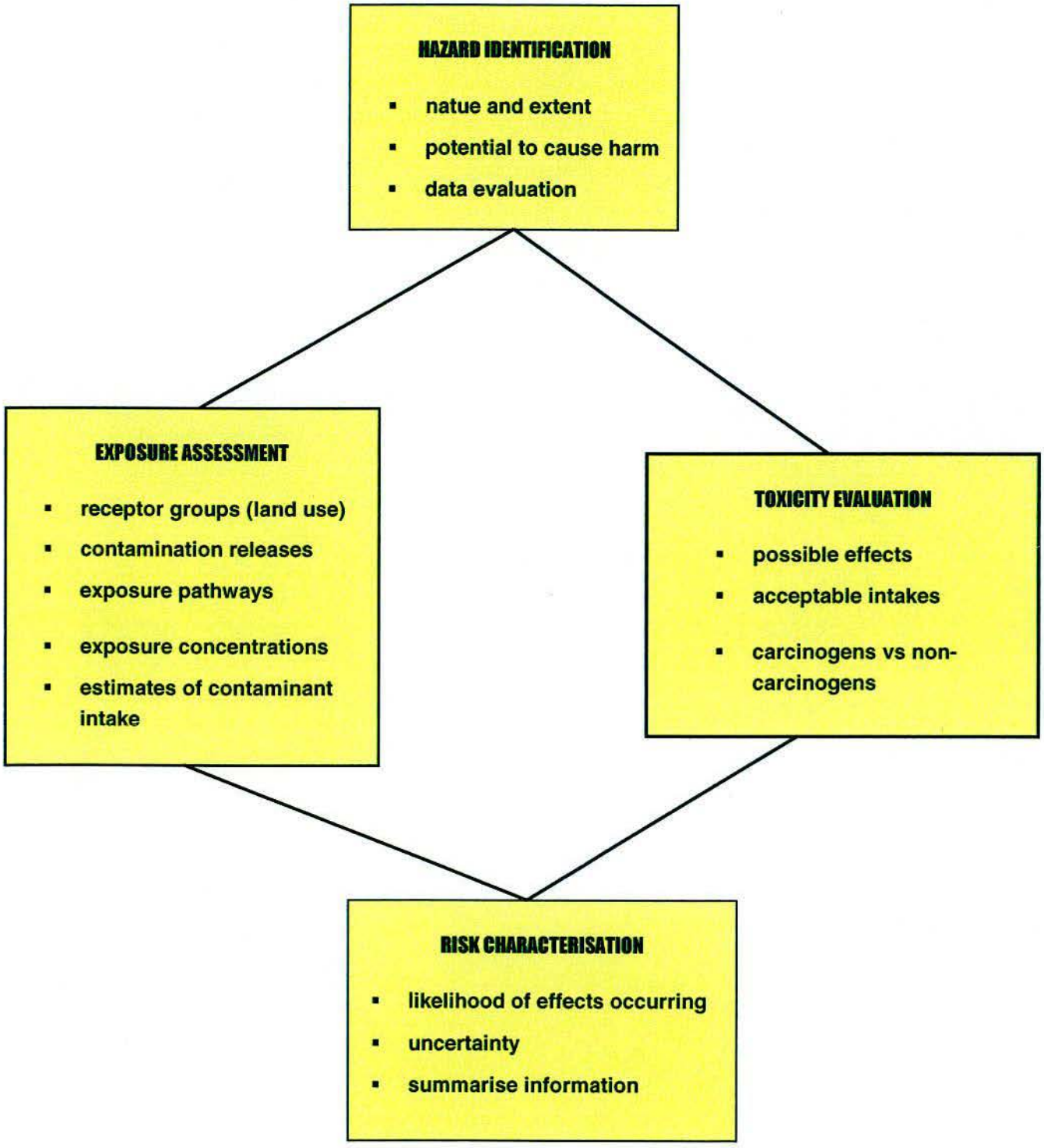
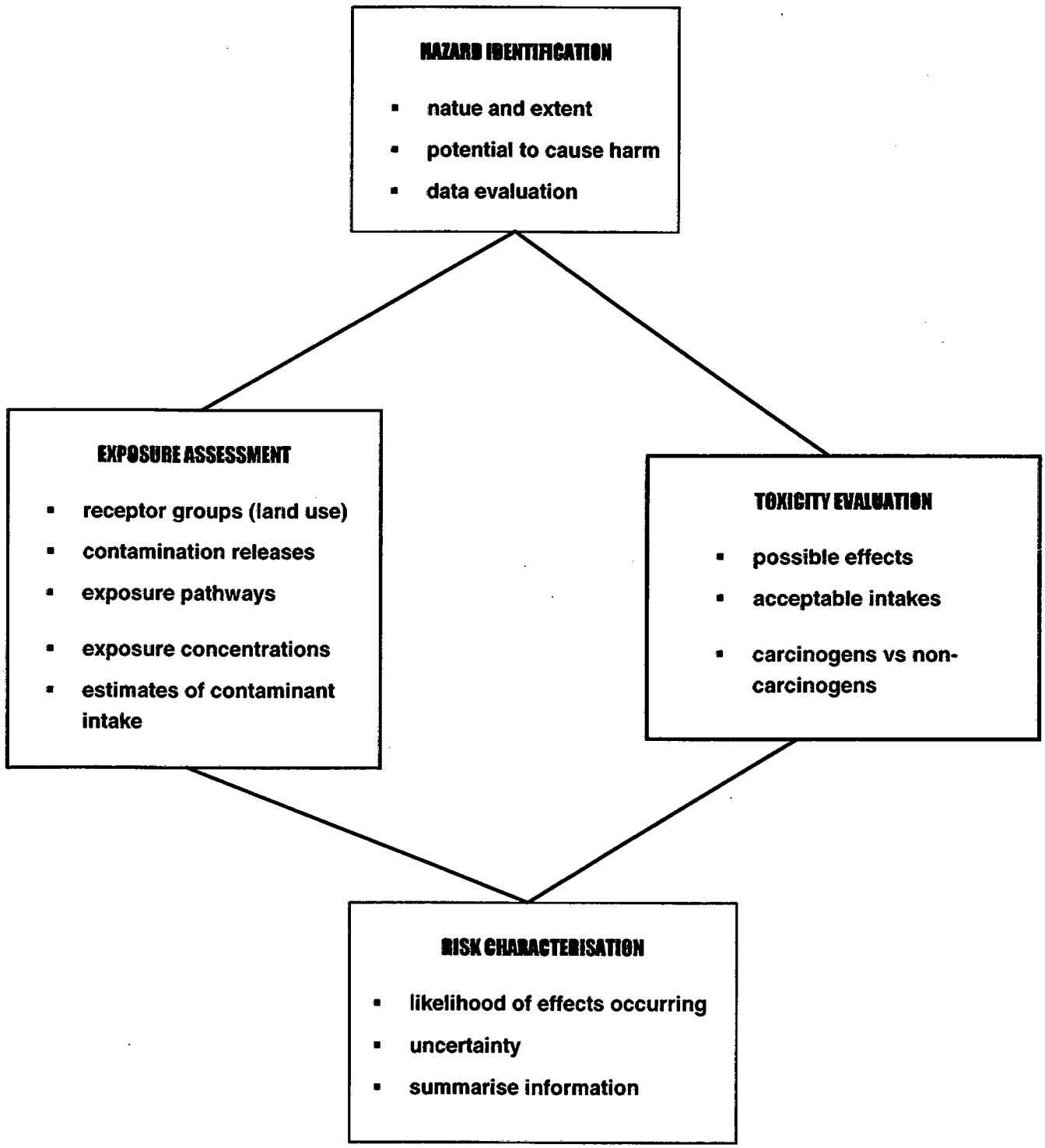
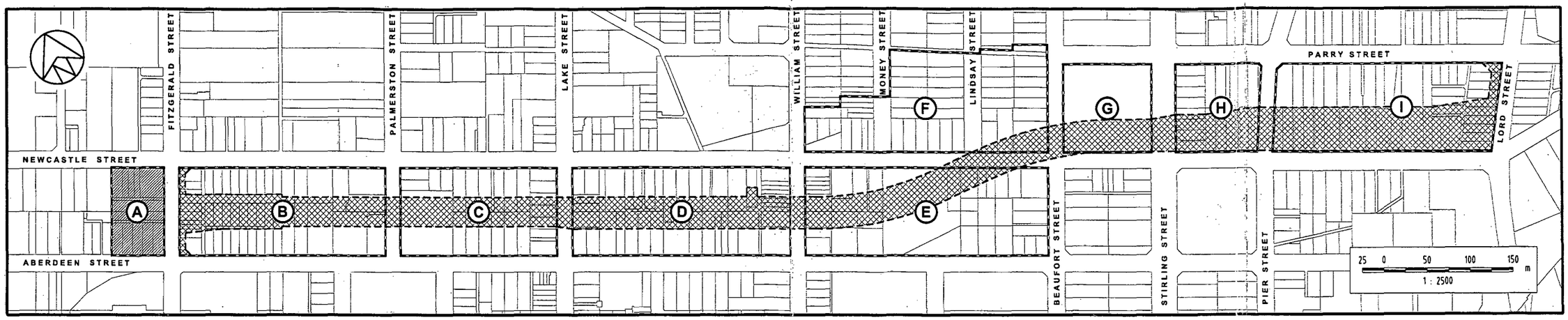


Figure 5 Health Risk Assessment Process





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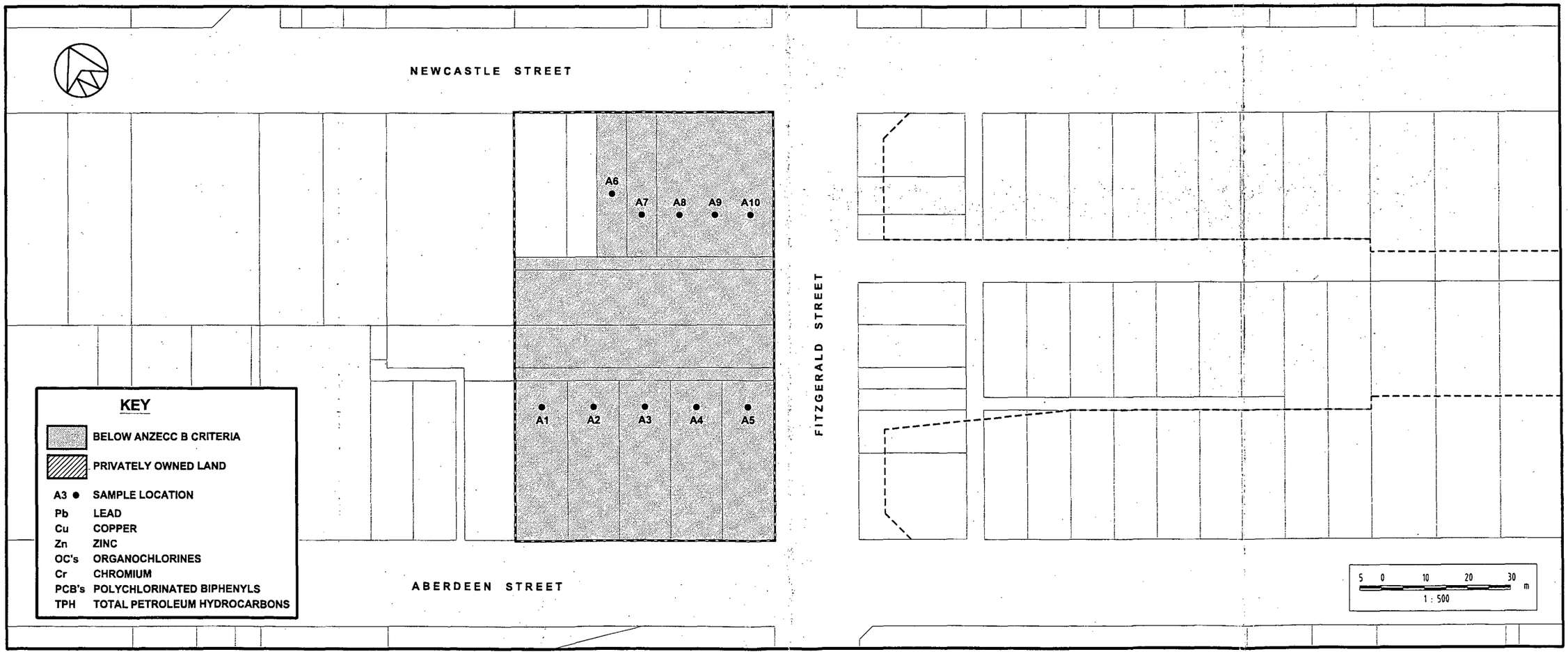

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NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK A

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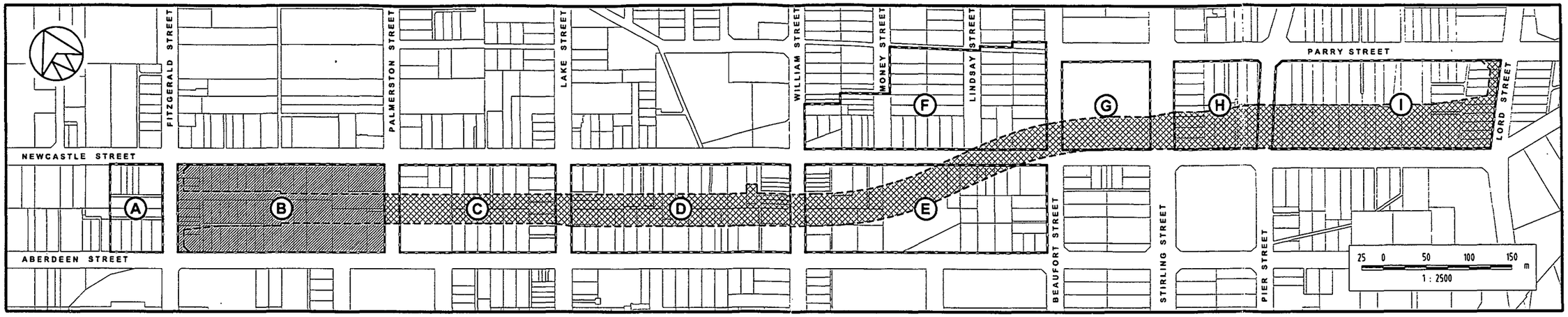

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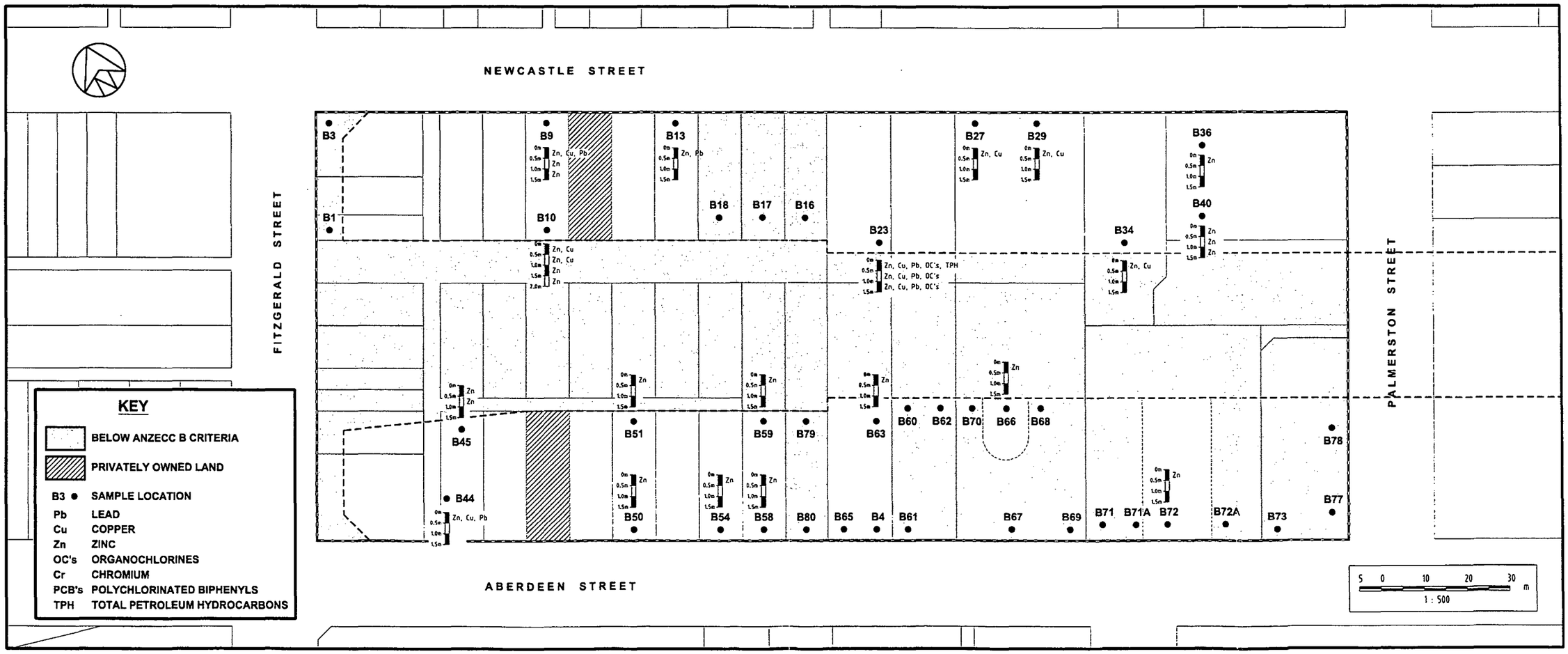

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SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK B

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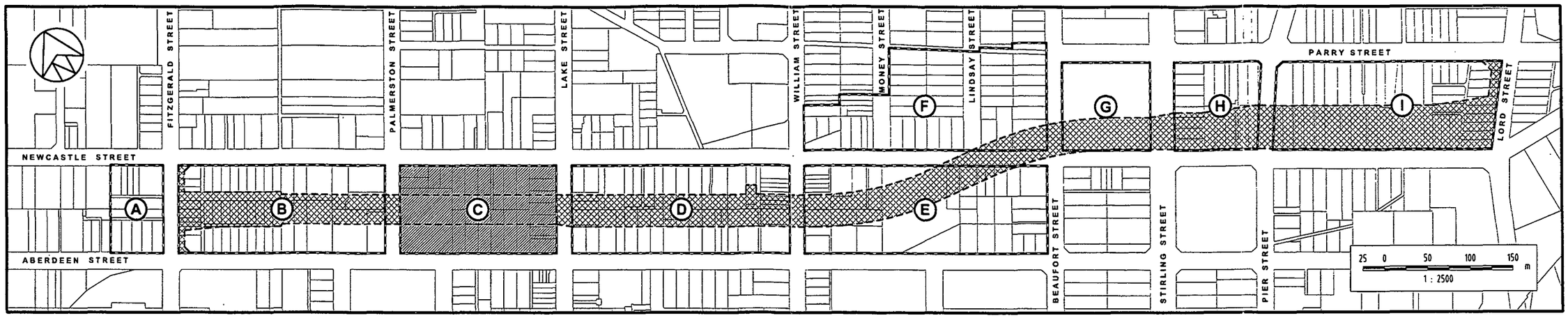

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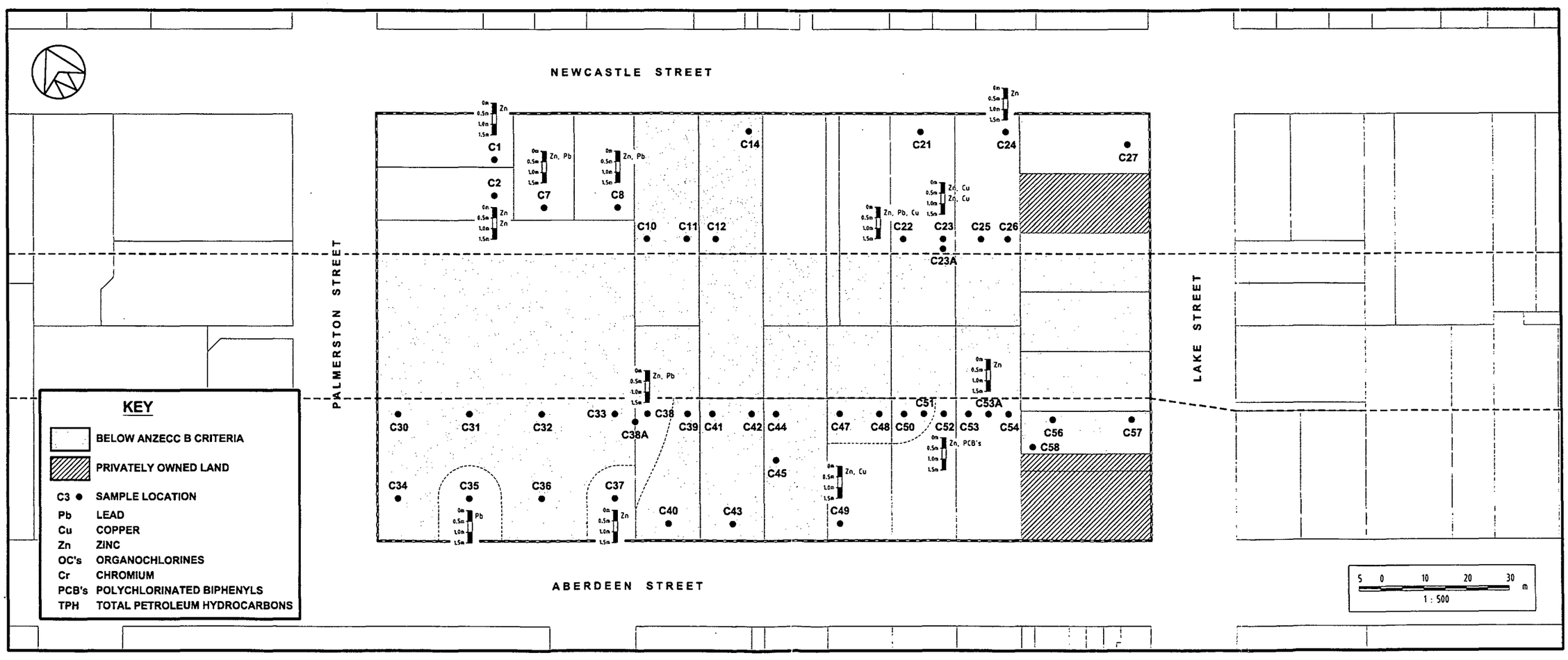

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TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK C

SIZE	PROJECT No	DRAWING No	SHEET No	REV
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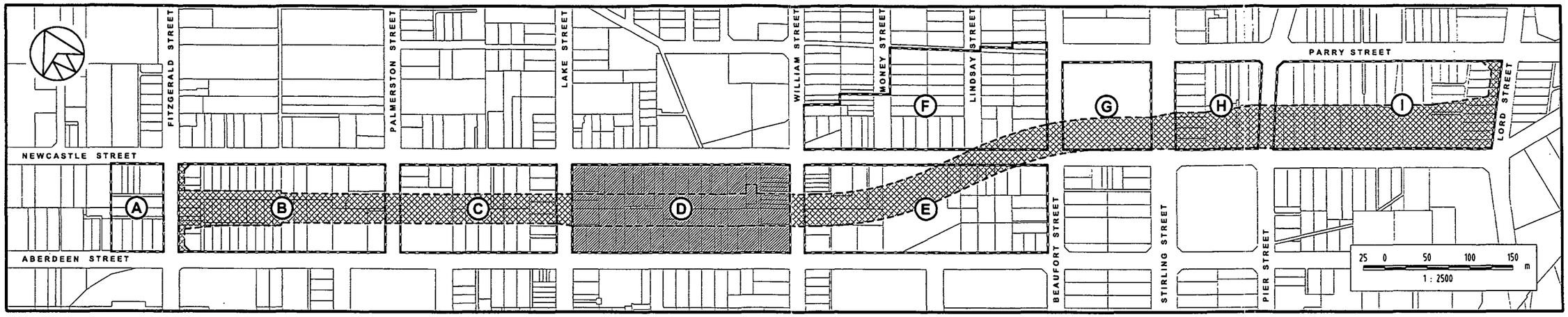

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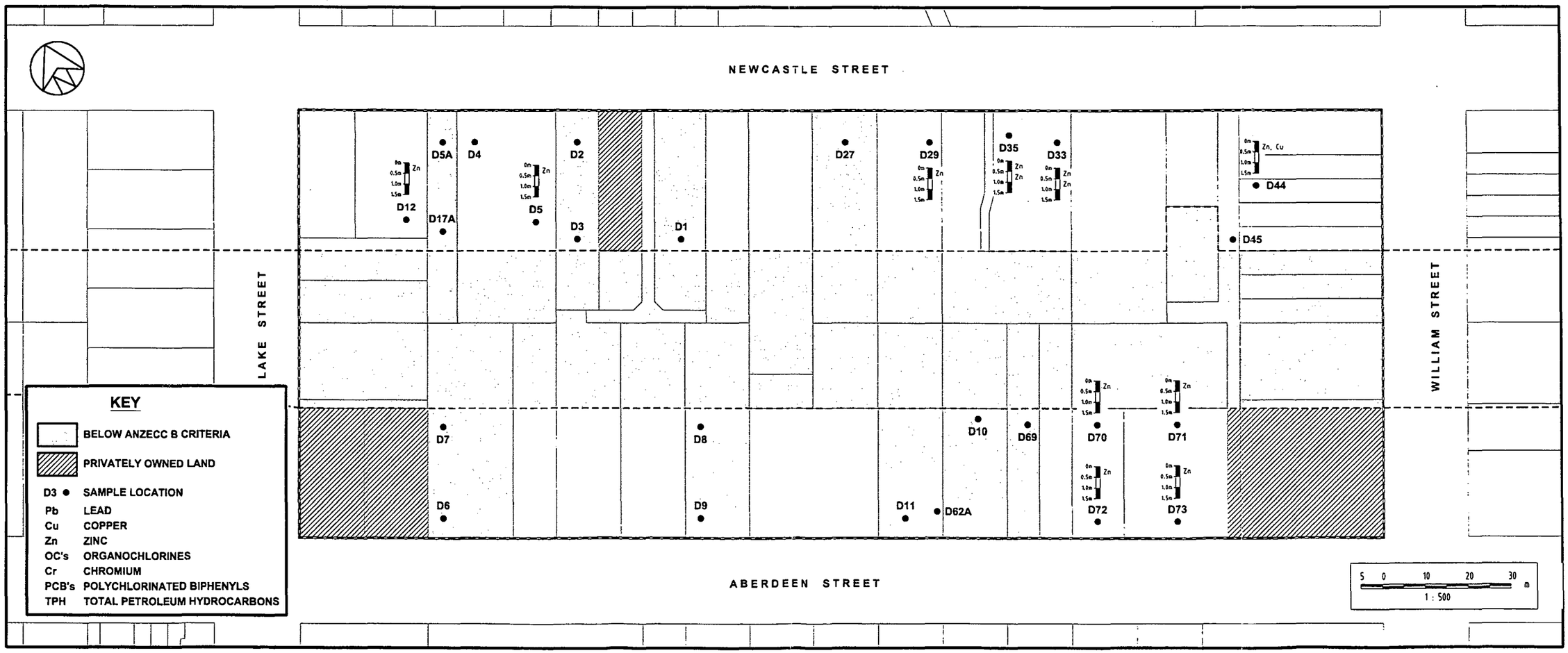

KEY

- BELOW ANZECC B CRITERIA
- PRIVATELY OWNED LAND
- D3 ● SAMPLE LOCATION
- Pb LEAD
- Cu COPPER
- Zn ZINC
- OC's ORGANOCHLORINES
- Cr CHROMIUM
- PCB's POLYCHLORINATED BIPHENYLS
- TPH TOTAL PETROLEUM HYDROCARBONS

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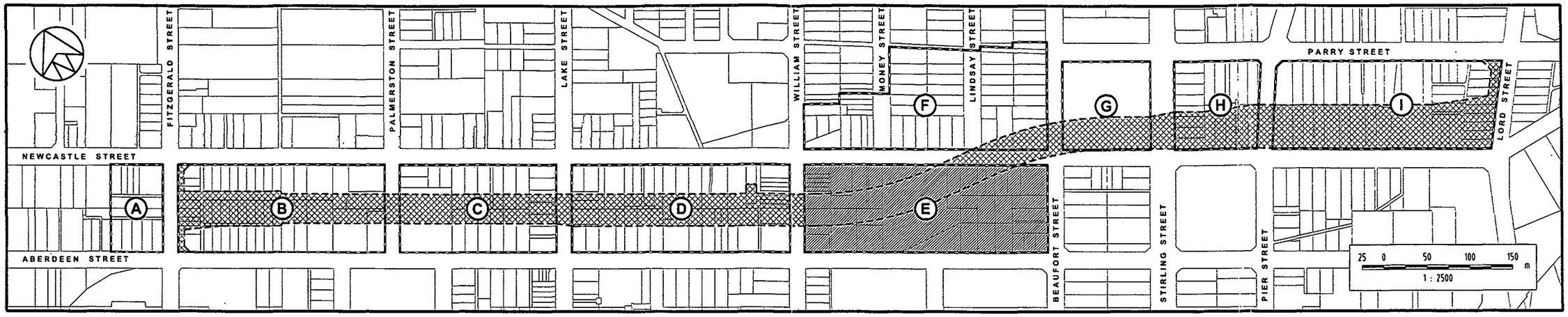

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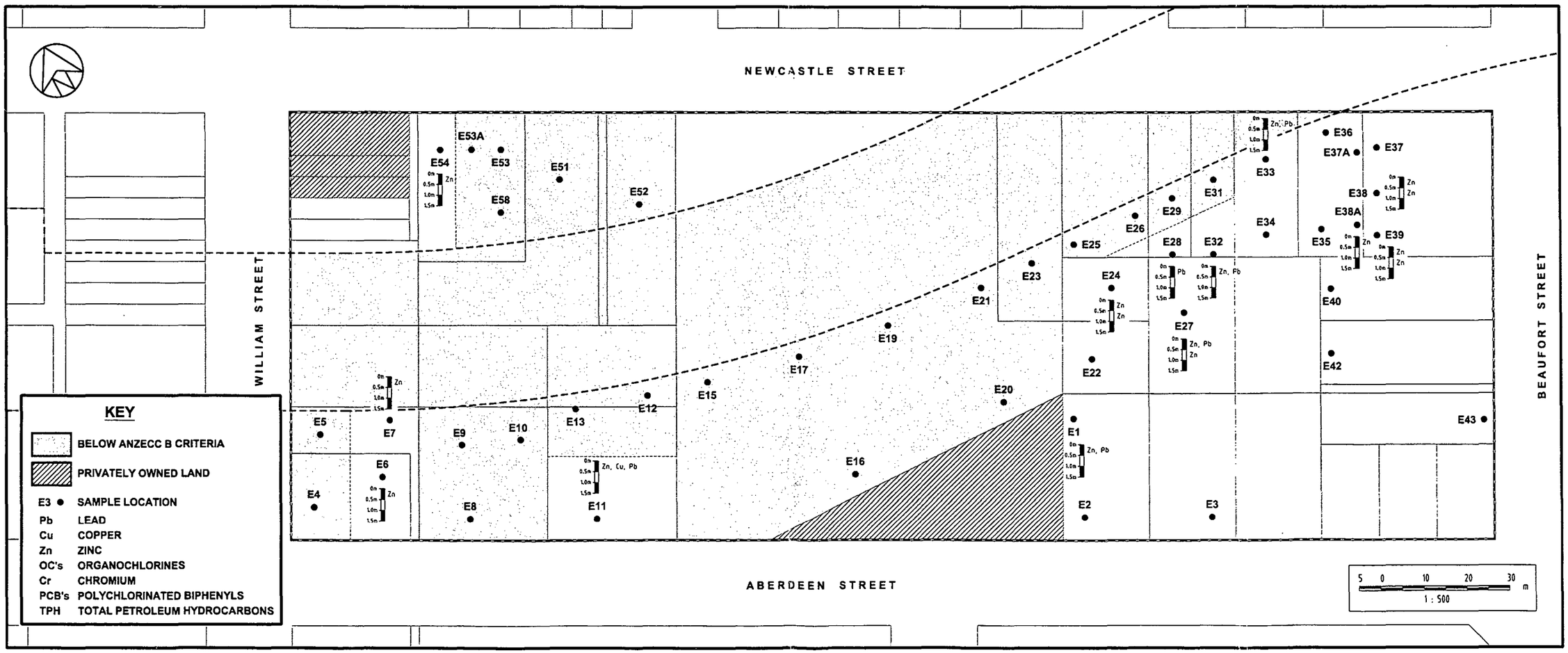

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- Zn ZINC
- OC's ORGANOCHLORINES
- Cr CHROMIUM
- PCB's POLYCHLORINATED BIPHENYLS
- TPH TOTAL PETROLEUM HYDROCARBONS

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SUPERVISOR			
MANAGER			
APPROVED			

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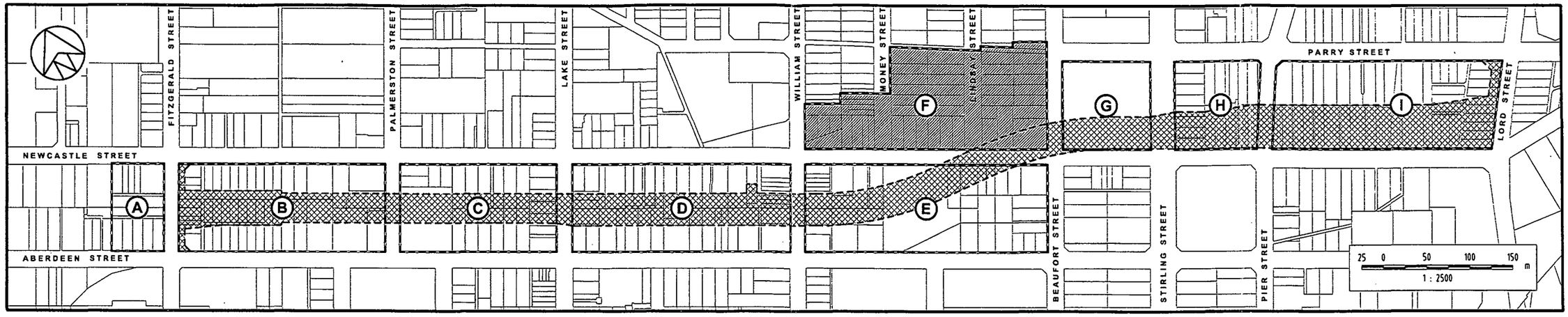
CAD FILE No 1216p005 | PLOT INFO XREFS 1:45 02/06/99

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK E

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 6E	OF	A



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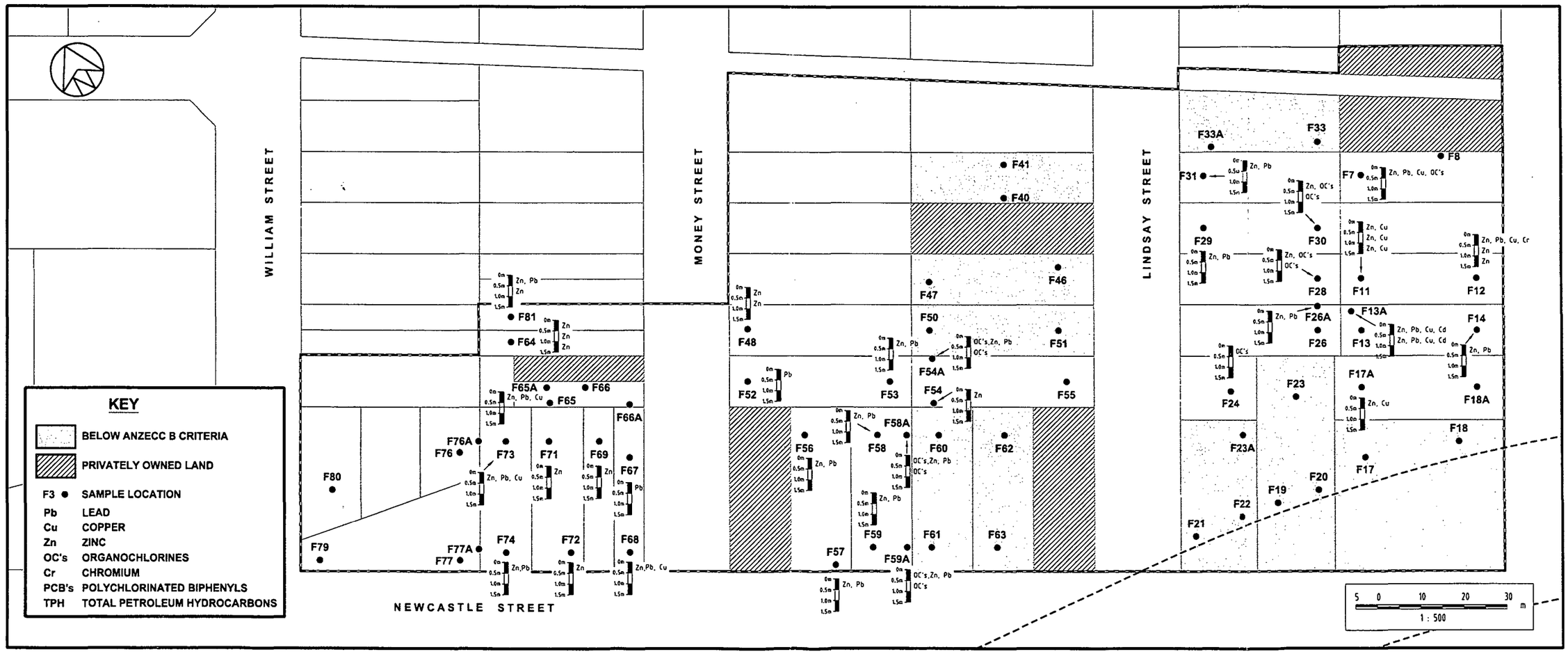

KEY

- BELOW ANZECC B CRITERIA
- PRIVATELY OWNED LAND
- F3 ● SAMPLE LOCATION
- Pb LEAD
- Cu COPPER
- Zn ZINC
- OC's ORGANOCHLORINES
- Cr CHROMIUM
- PCB's POLYCHLORINATED BIPHENYLS
- TPH TOTAL PETROLEUM HYDROCARBONS

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
ORG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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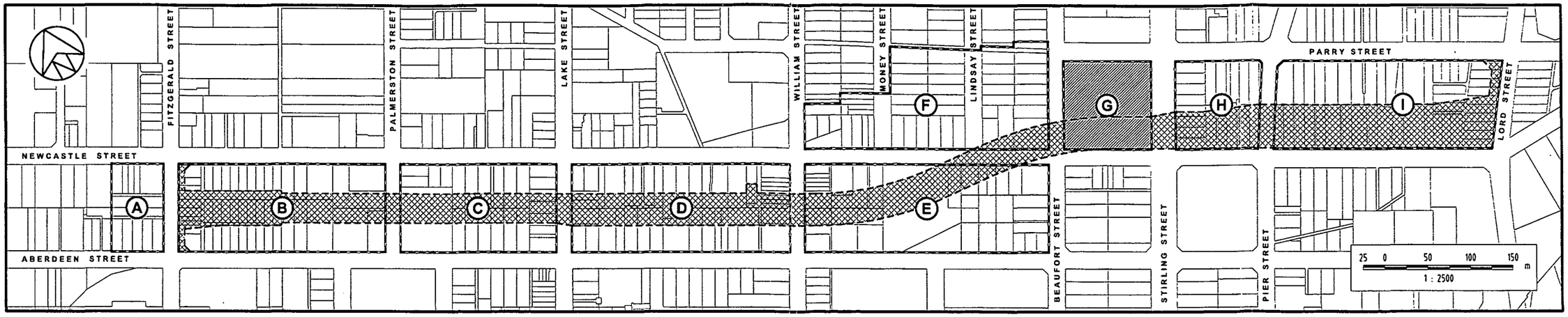
CAD FILE No 1216p006 | PLOT INFO XREFS 11:51 02/06/99

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK F

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 6F	OF	A



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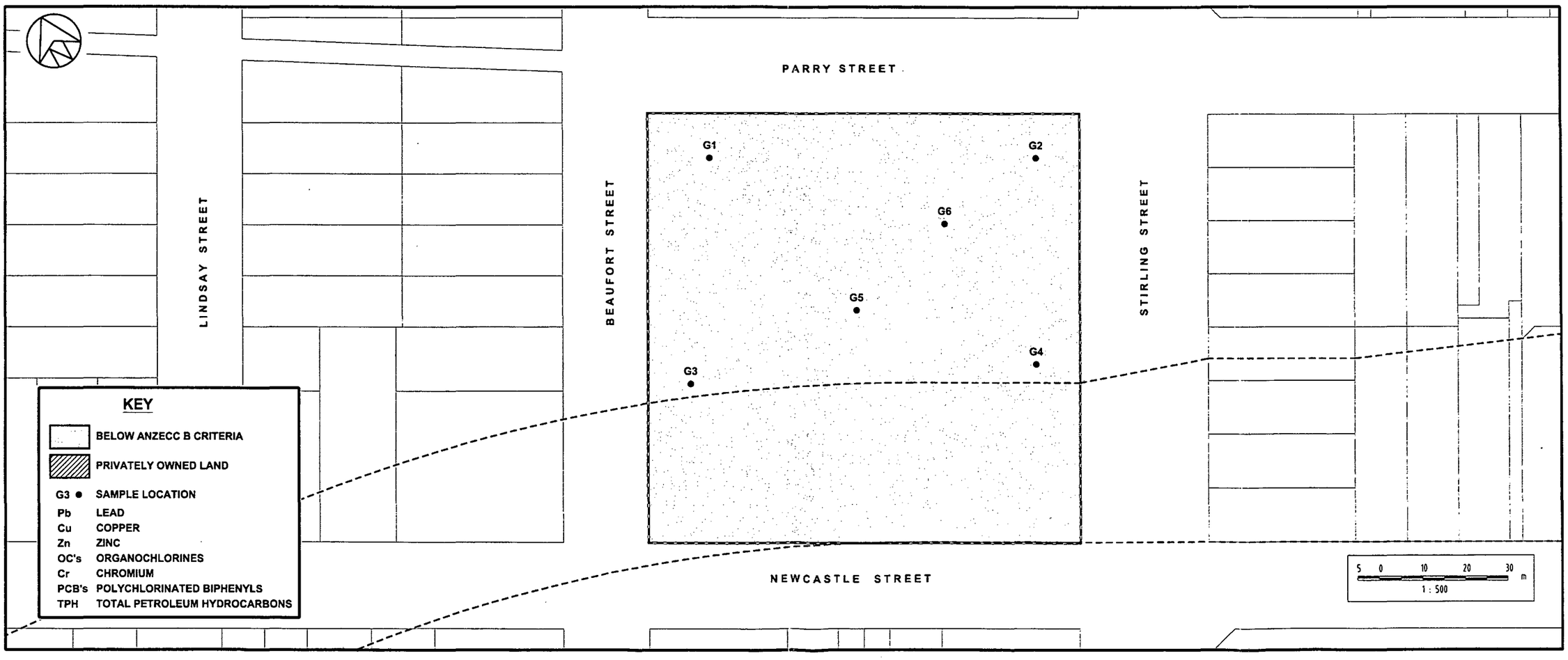

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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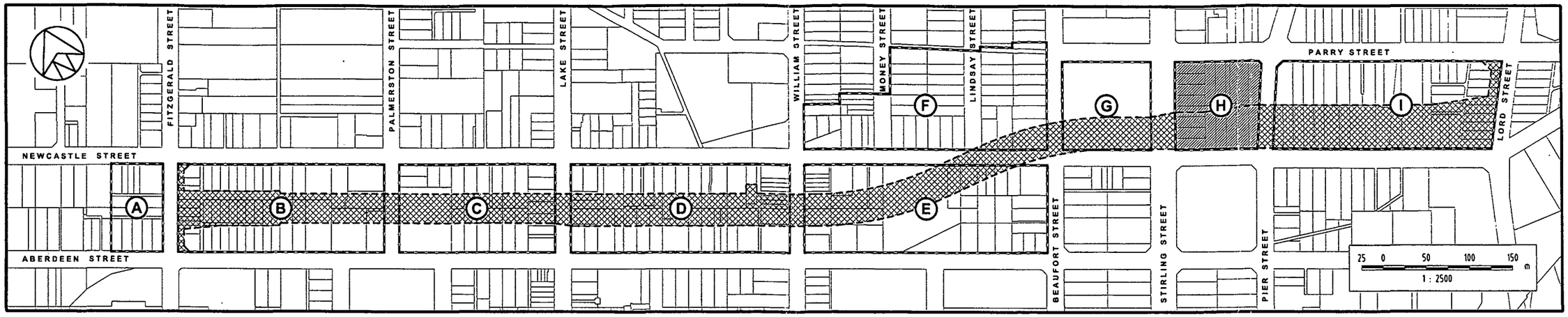
CAD FILE No 1216p007 | PLOT INFO XREFS 11:54 02/06/99

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK G

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 6G	OF	A



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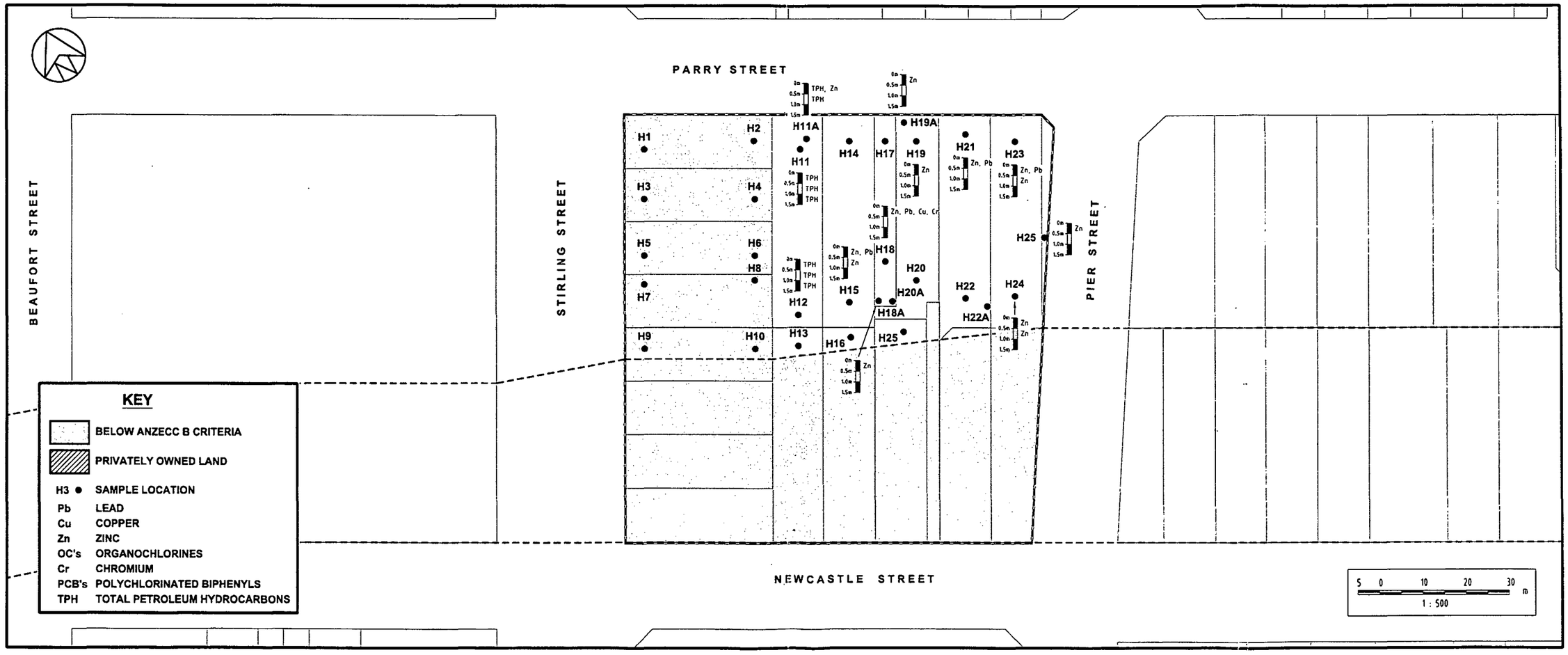

KEY

- BELOW ANZECC B CRITERIA
- PRIVATELY OWNED LAND
- H3 ● SAMPLE LOCATION
- Pb LEAD
- Cu COPPER
- Zn ZINC
- OC's ORGANOCHLORINES
- Cr CHROMIUM
- PCB's POLYCHLORINATED BIPHENYLS
- TPH TOTAL PETROLEUM HYDROCARBONS

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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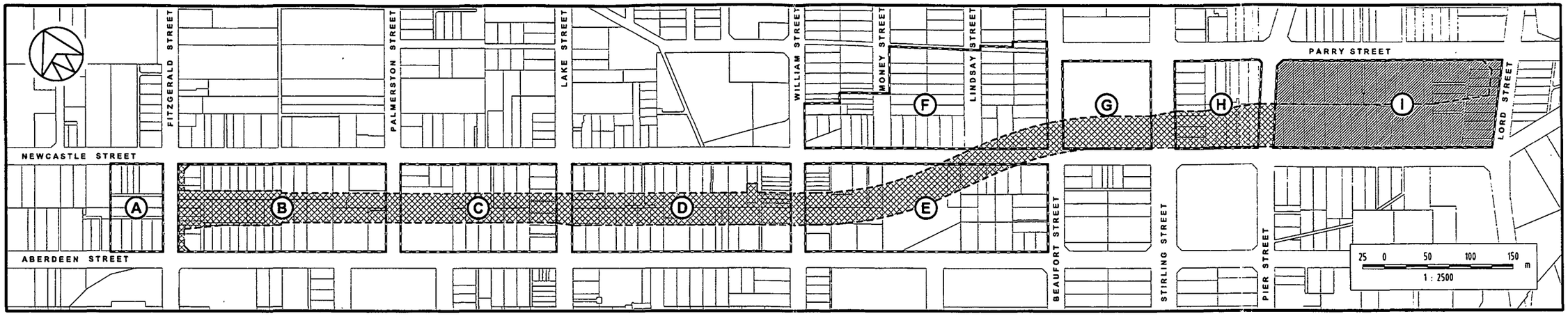
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK H

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 6H	OF	A

CAD FILE No 1216p008 | PLOT INFO XREFS 11:57 02/06/99



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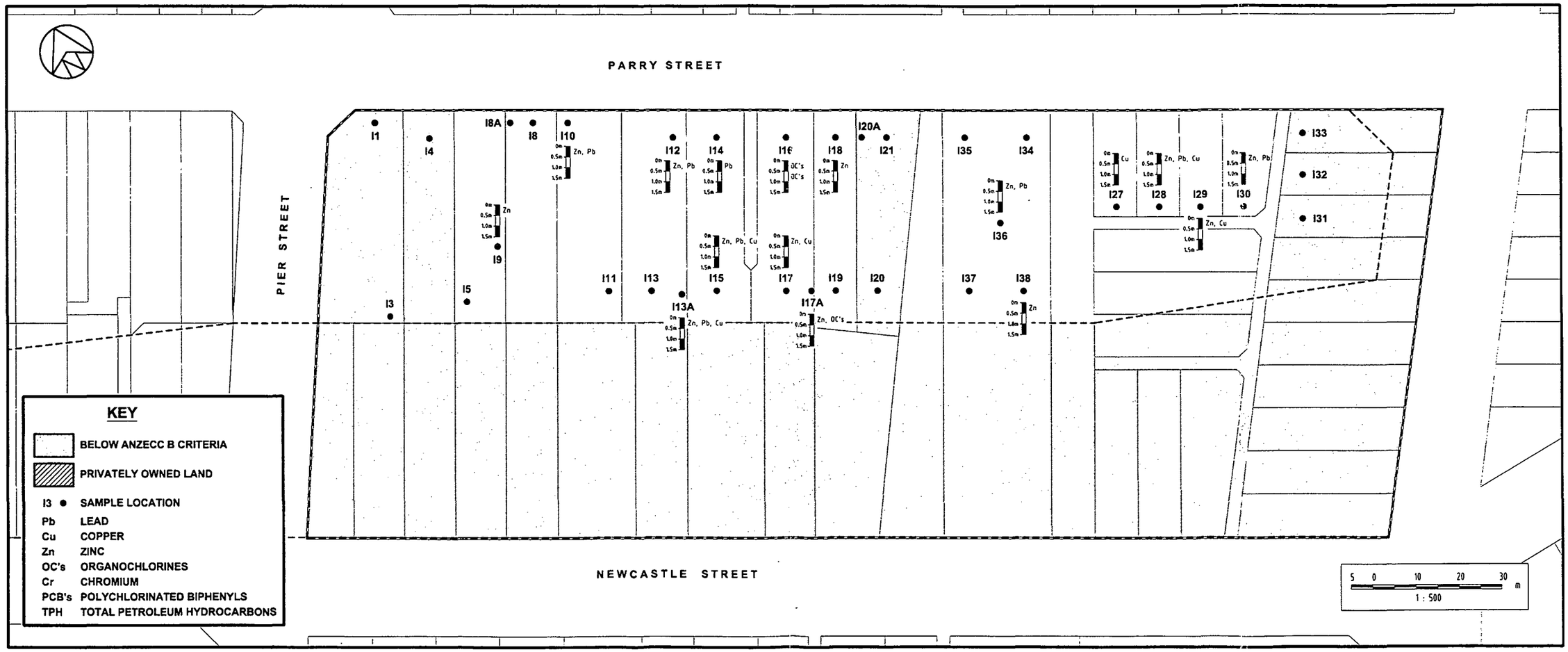

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A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
ORG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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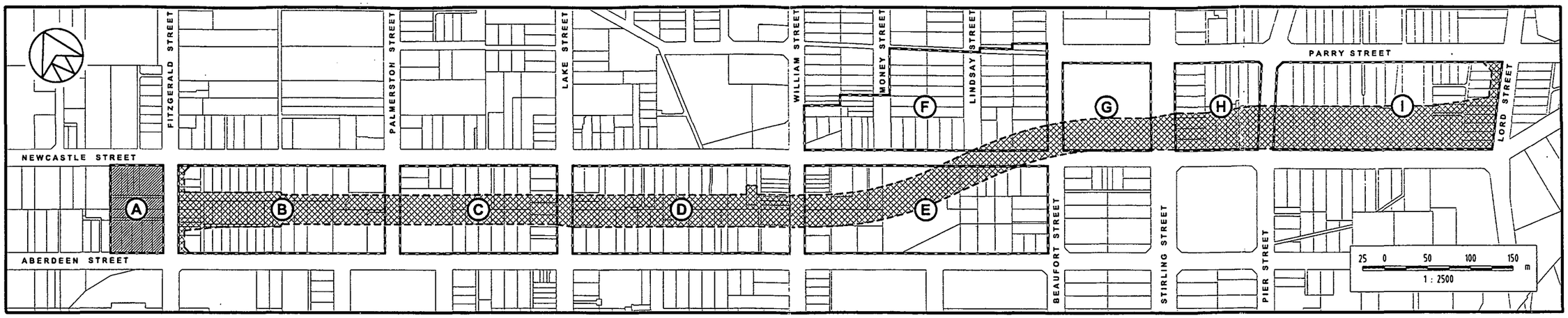
CAD FILE No 1216p009 | PLOT INFO XREFS 12:00 02/06/99

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW ENVIRONMENTAL GUIDELINES
BLOCK 1

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 61	OF	A



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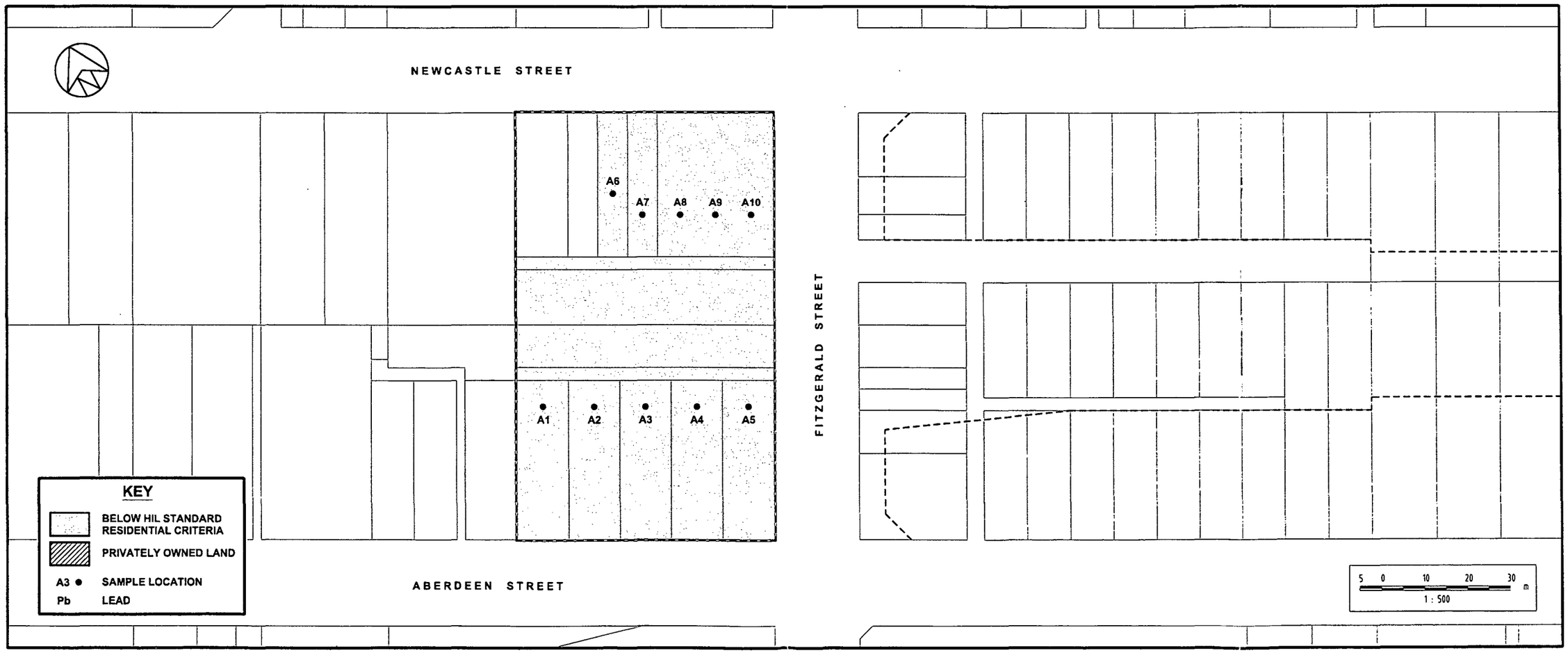

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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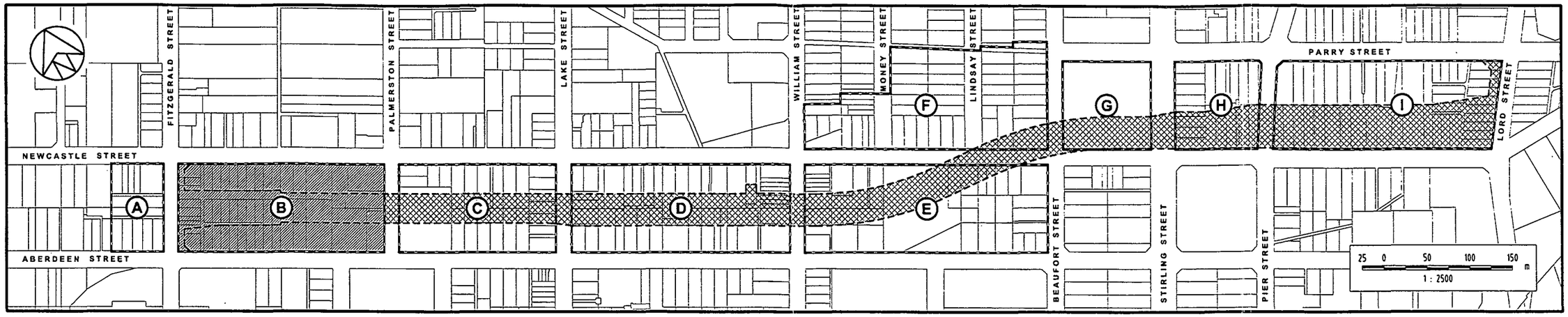
TITLE
NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK A

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7A	OF	A

CAD FILE No 1216p101
PLOT INFO XREFS 13:25 02/06/99



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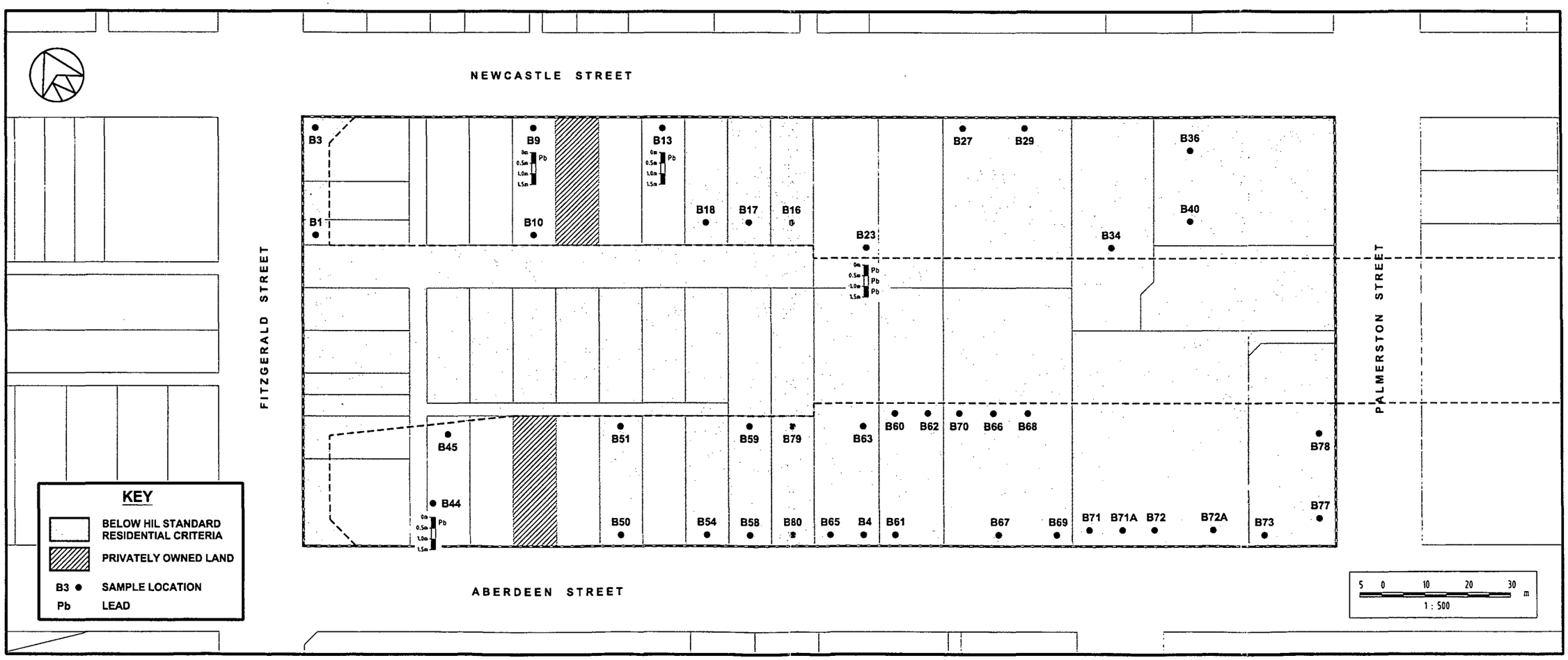

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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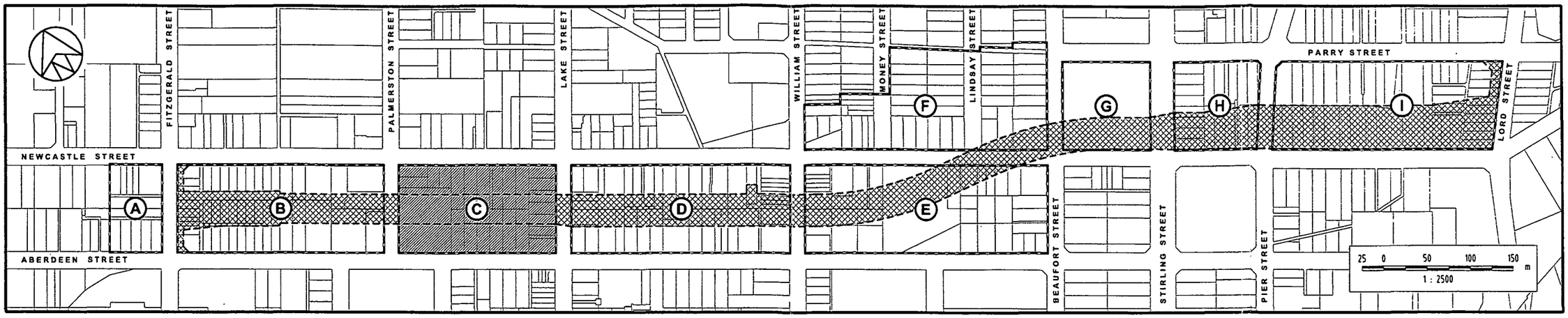
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK B

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7B	OF	A

CAD FILE No 1216p102 PLOT INFO XREFS 13:36 02/06/99



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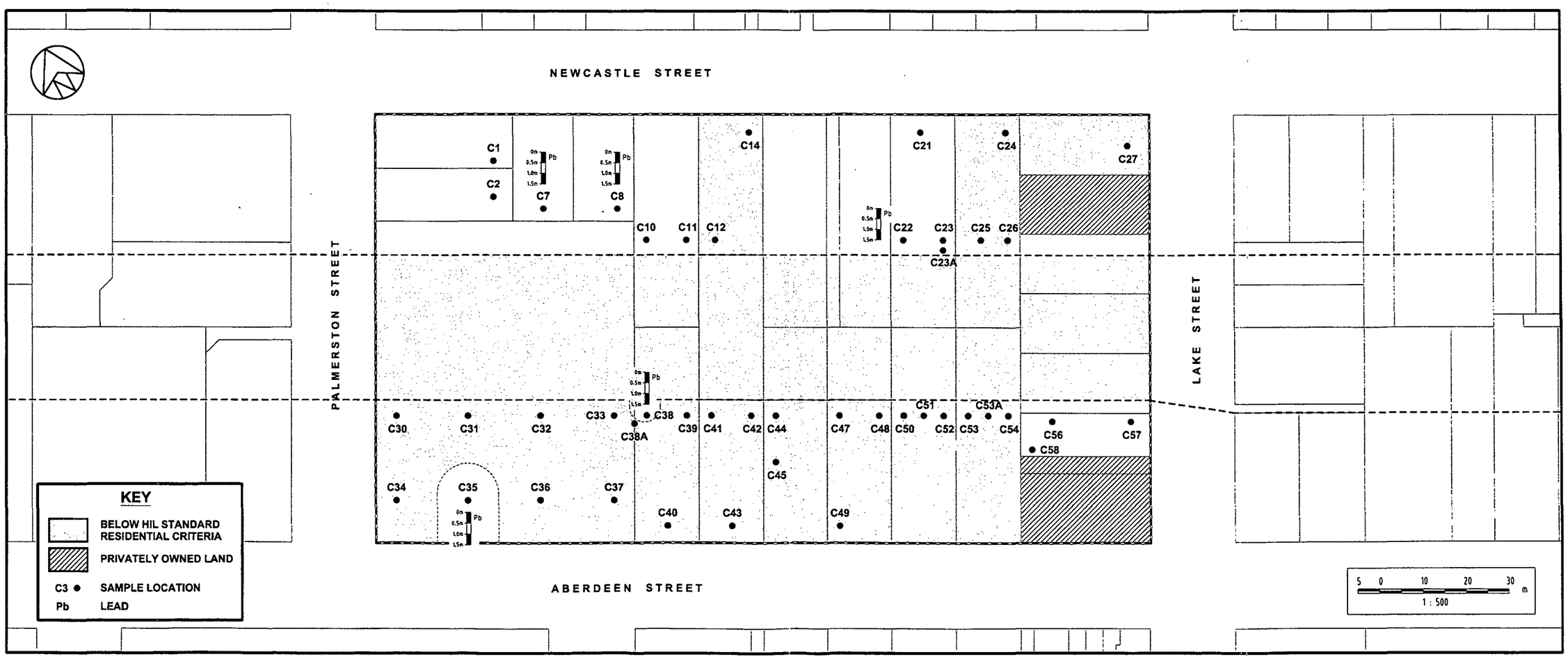

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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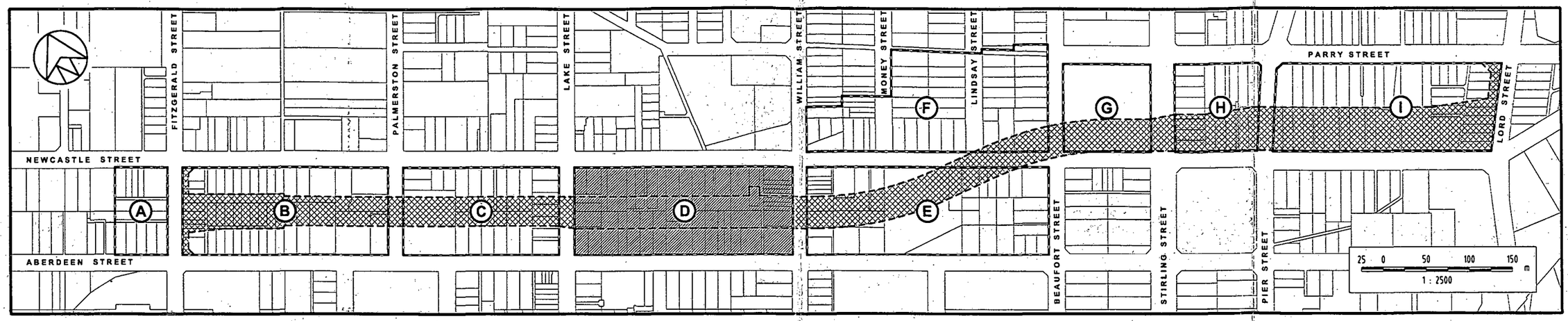
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK C

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7C	OF	A

CAD FILE No 1216p103 | PLOT INFO XREFS 13:34 02/06/99



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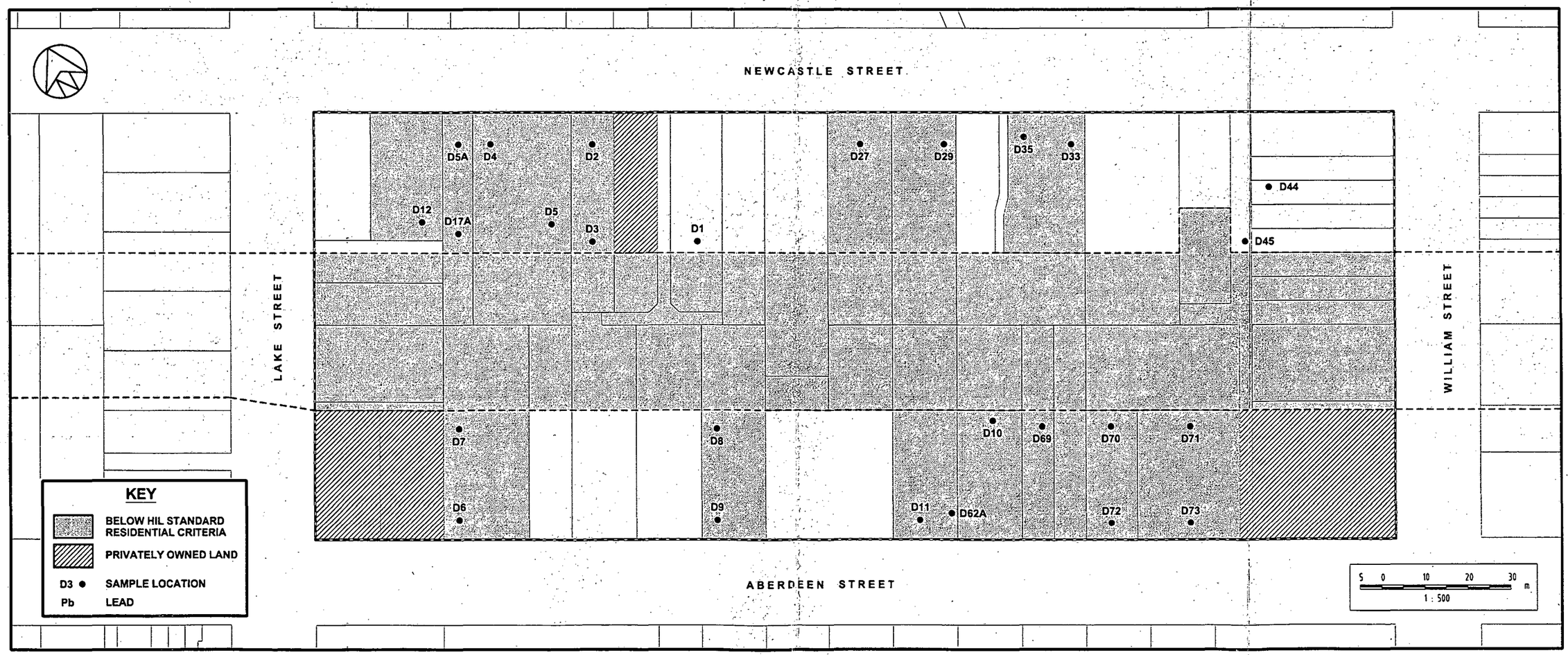

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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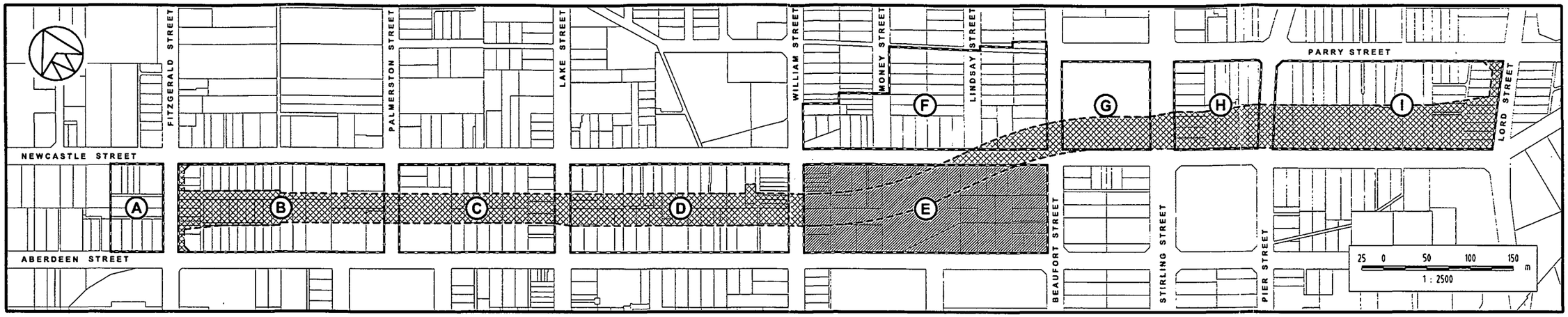
A.C.N. 000 912 630

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK D

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7D	OF	A

CAD FILE No 1216p104 | PLOT INFO XREFS 14:07 02/06/99



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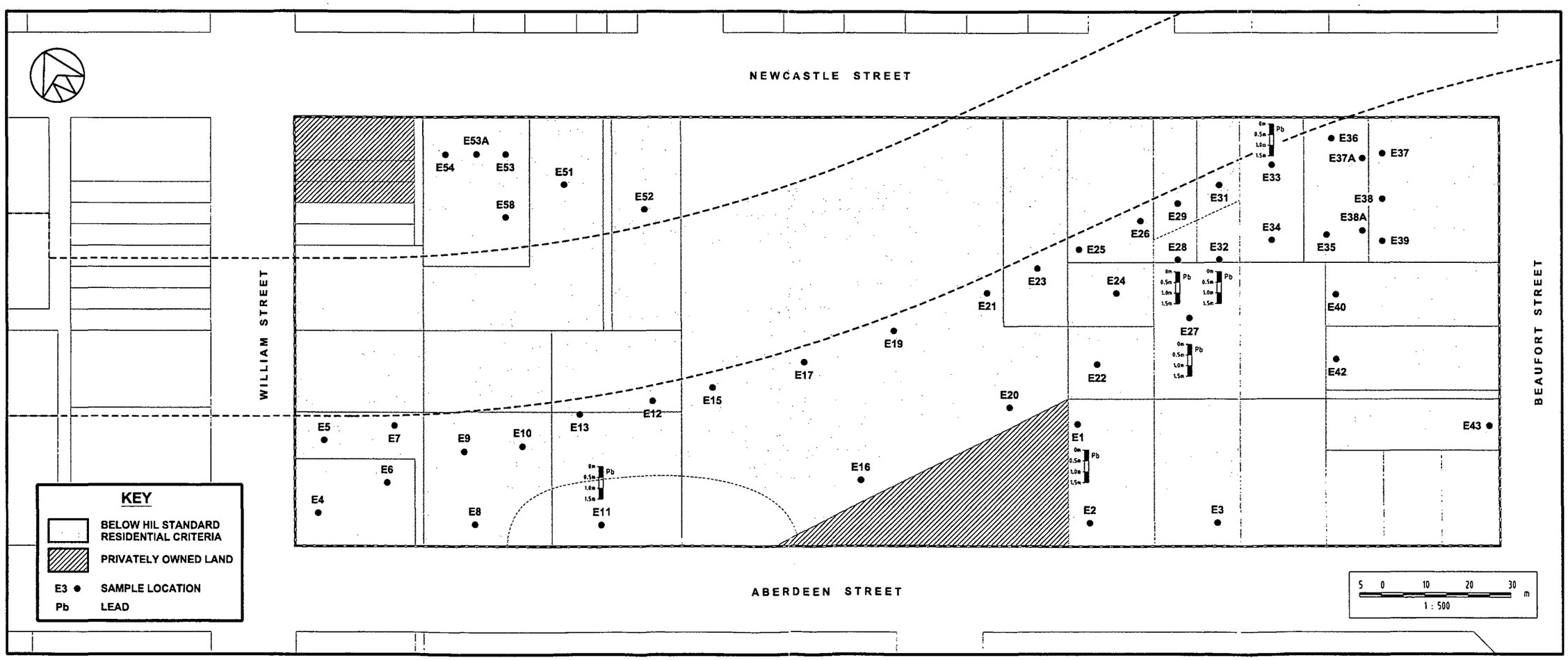

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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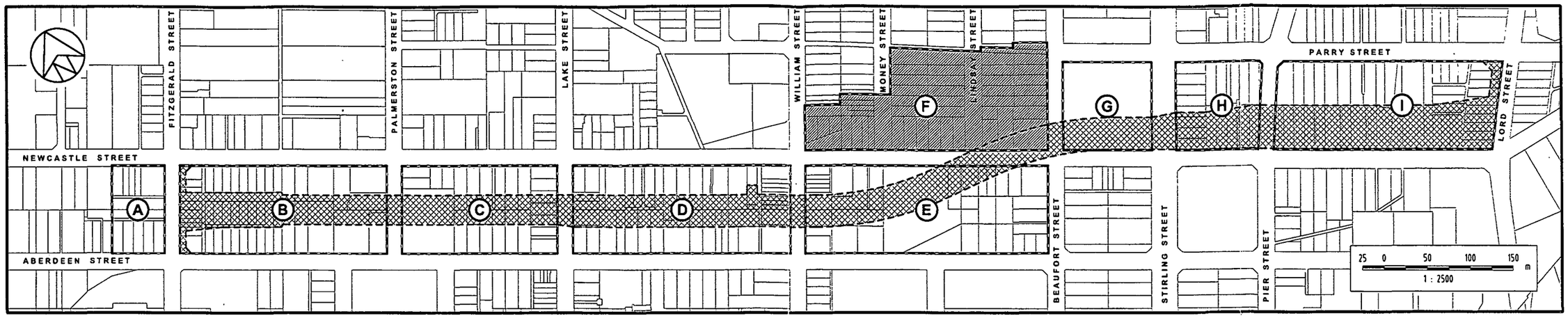
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK E

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7E	OF	A

CAD FILE No 1216p105 | PLOT INFO 14:03 02/06/99 | XREFS



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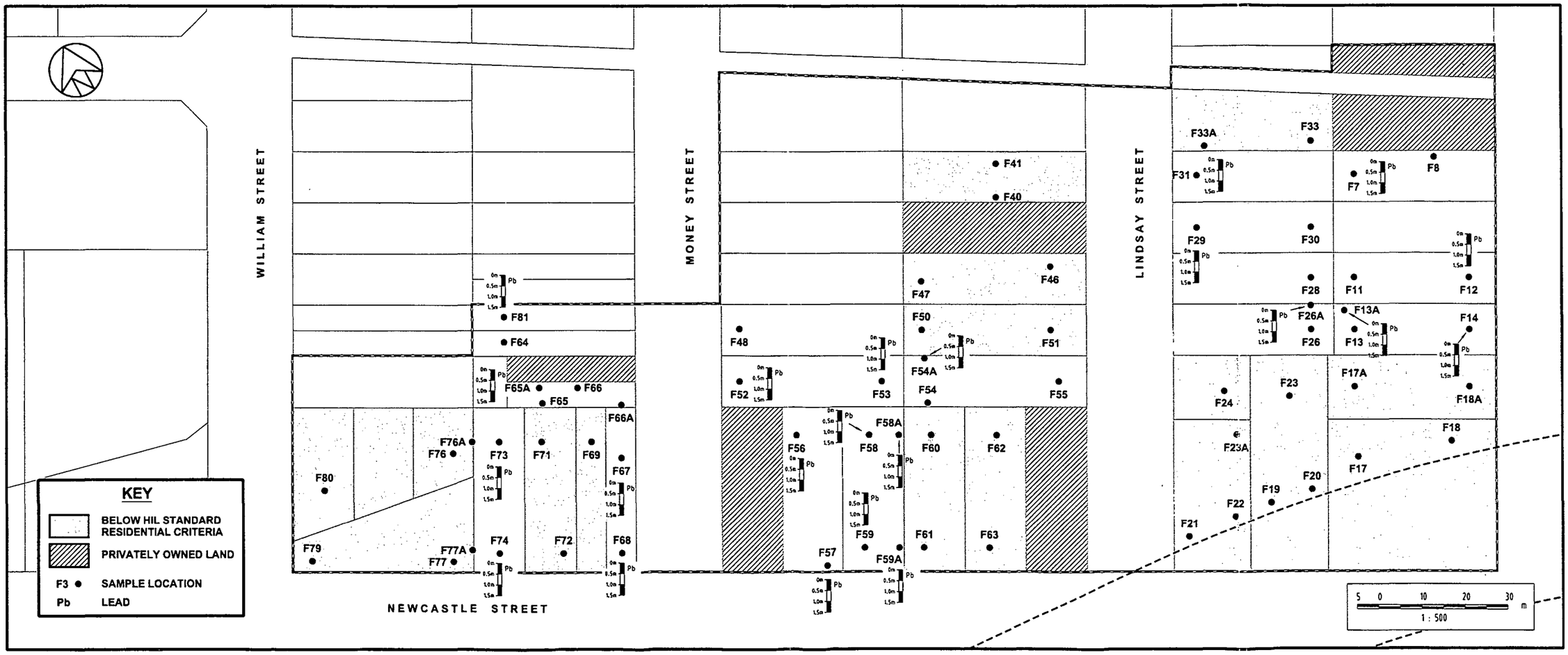

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
ORG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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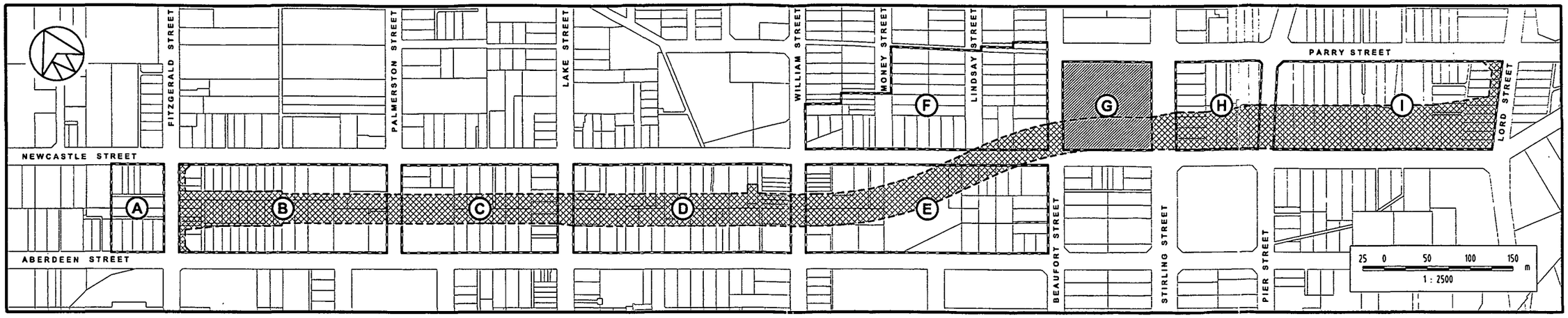
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK F

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7F	OF	A

CAD FILE No 1216p106 | PLOT INFO XREFS 14:01 02/06/99



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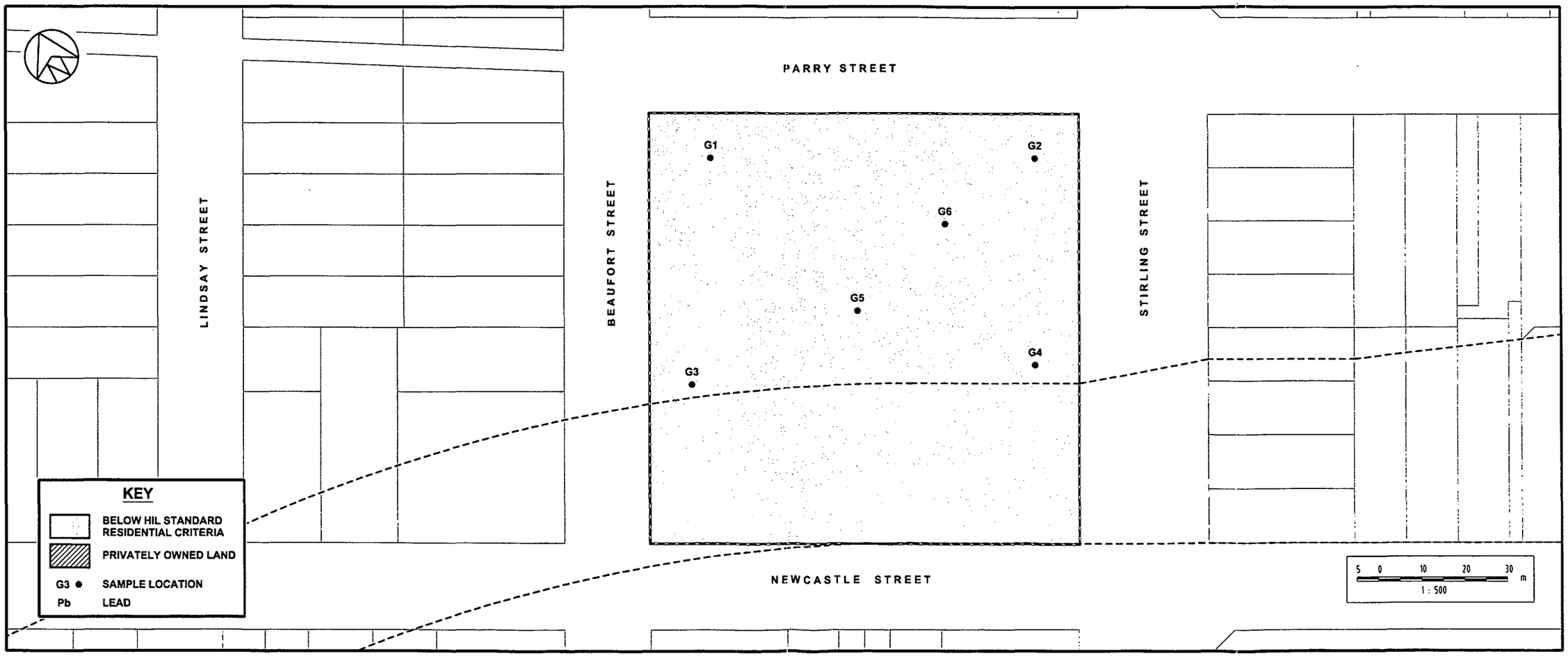

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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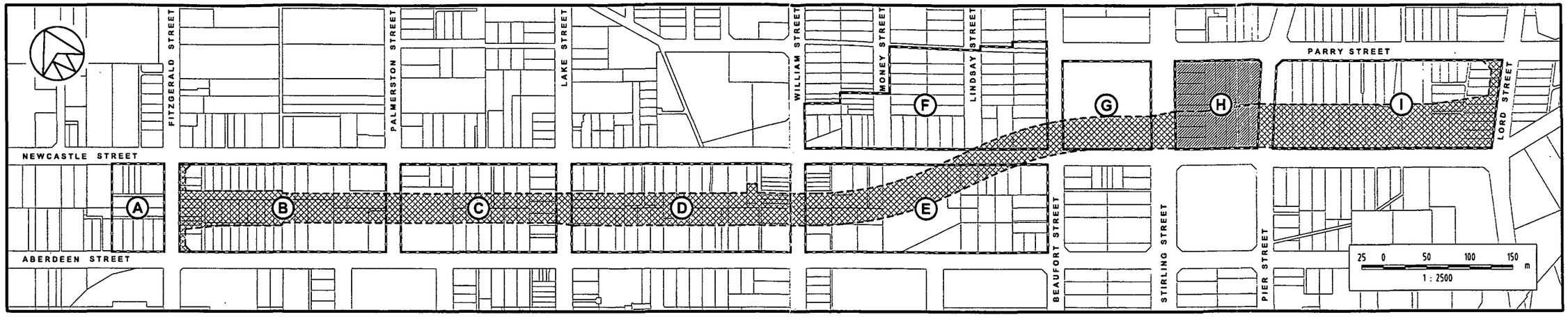
CAD FILE No 1216p107 | PLOT INFO XREFS 13:52 02/06/99

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK G

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7G	OF	A



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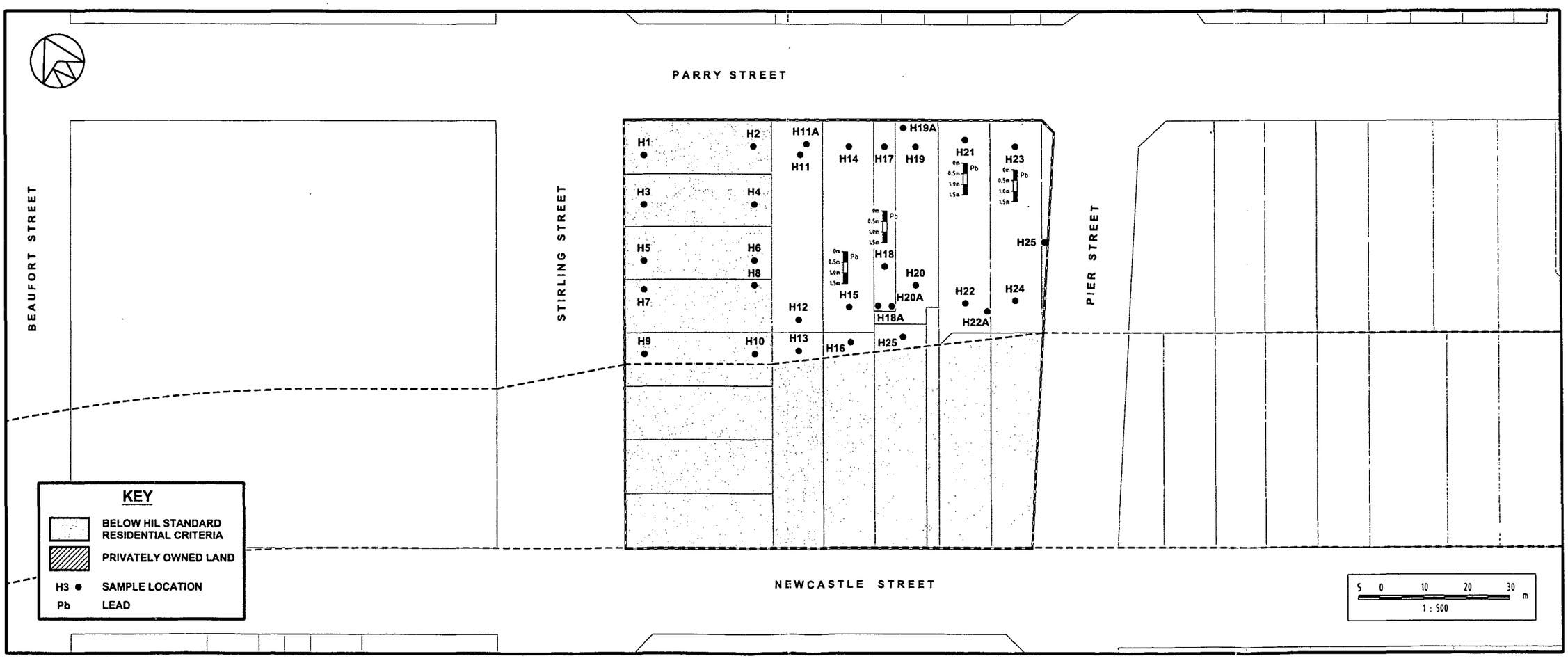

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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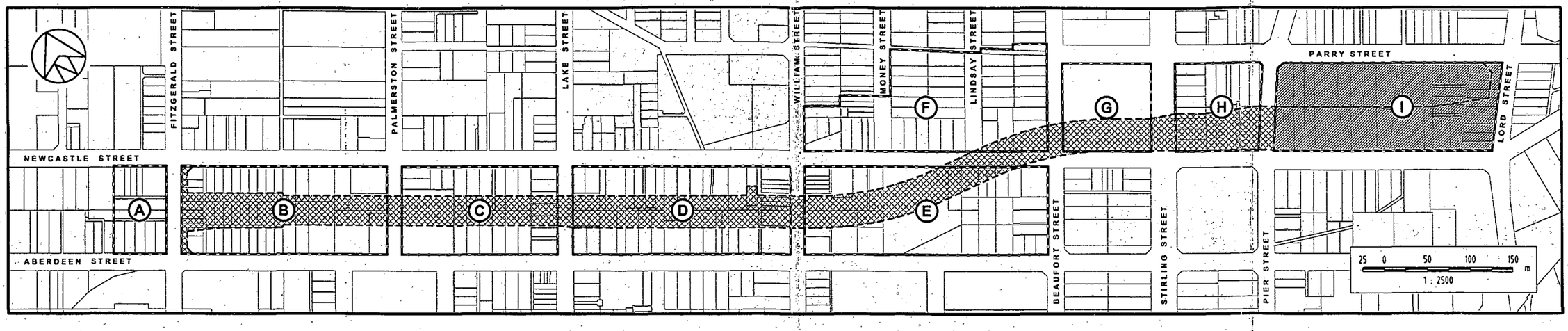
CAD FILE No 1216p108 | PLOT INFO XREFS 13:54 02/06/99

TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK H

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 7H	OF	A



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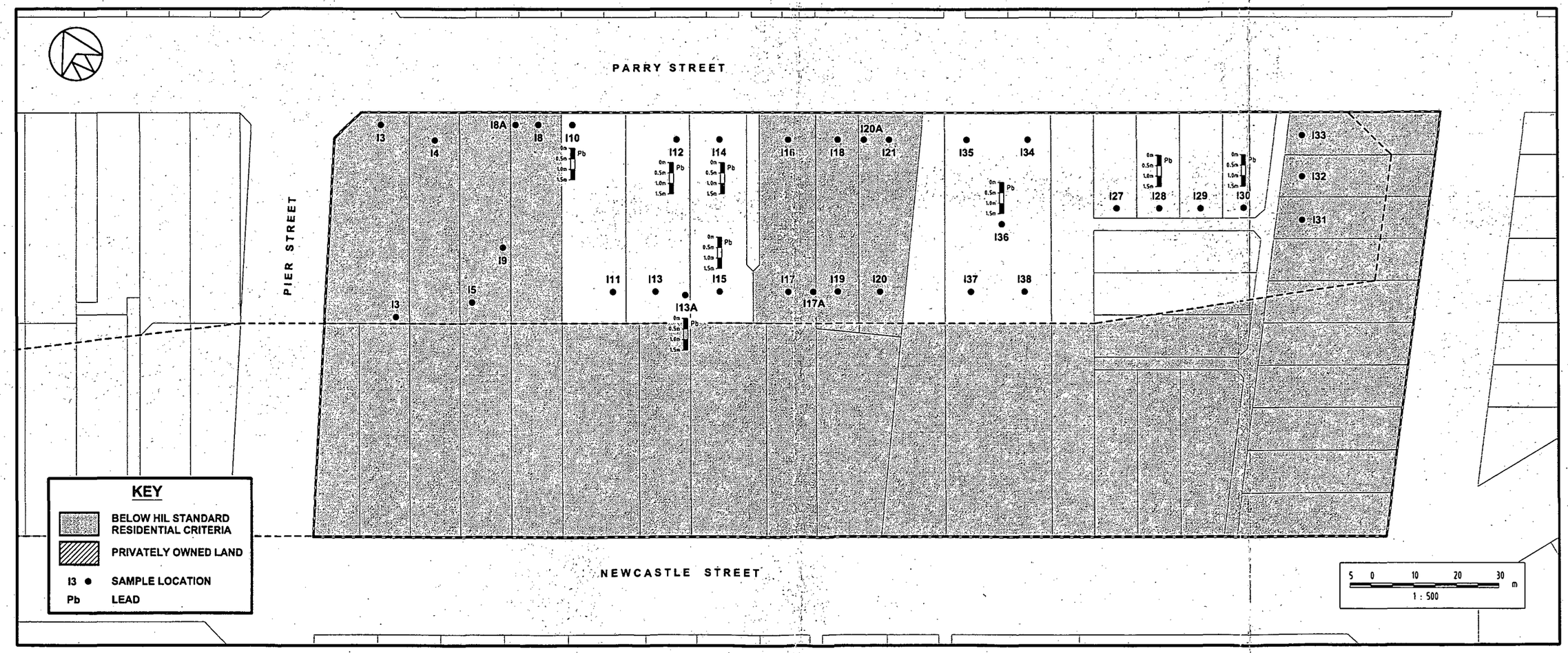

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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PERTH WA 6000
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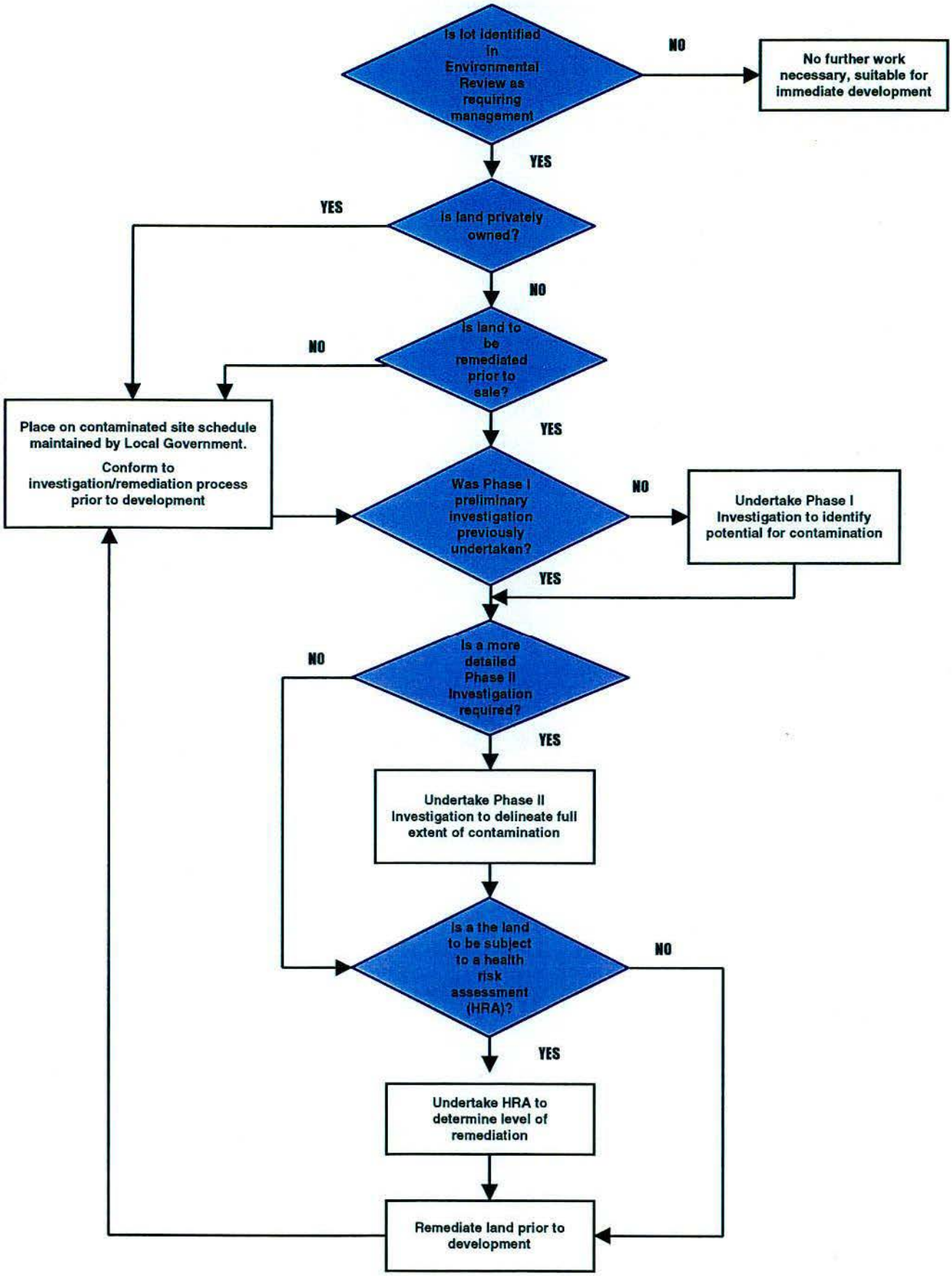
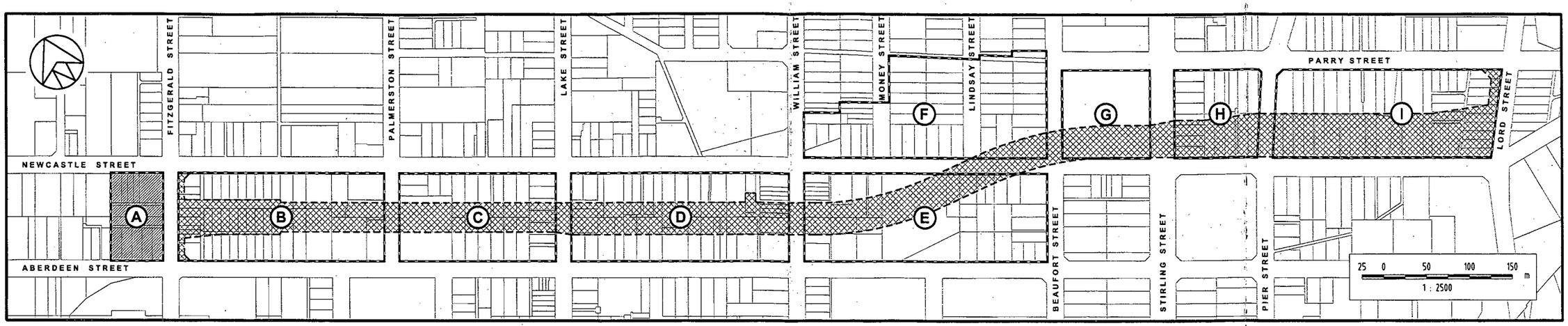
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
BELOW HEALTH GUIDELINES
BLOCK 1

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 71	OF	A

CAD FILE No 1216p109 | PLOT INFO XREFS 13:58 02/06/99

Figure 8 : Soil Contamination Management Strategy





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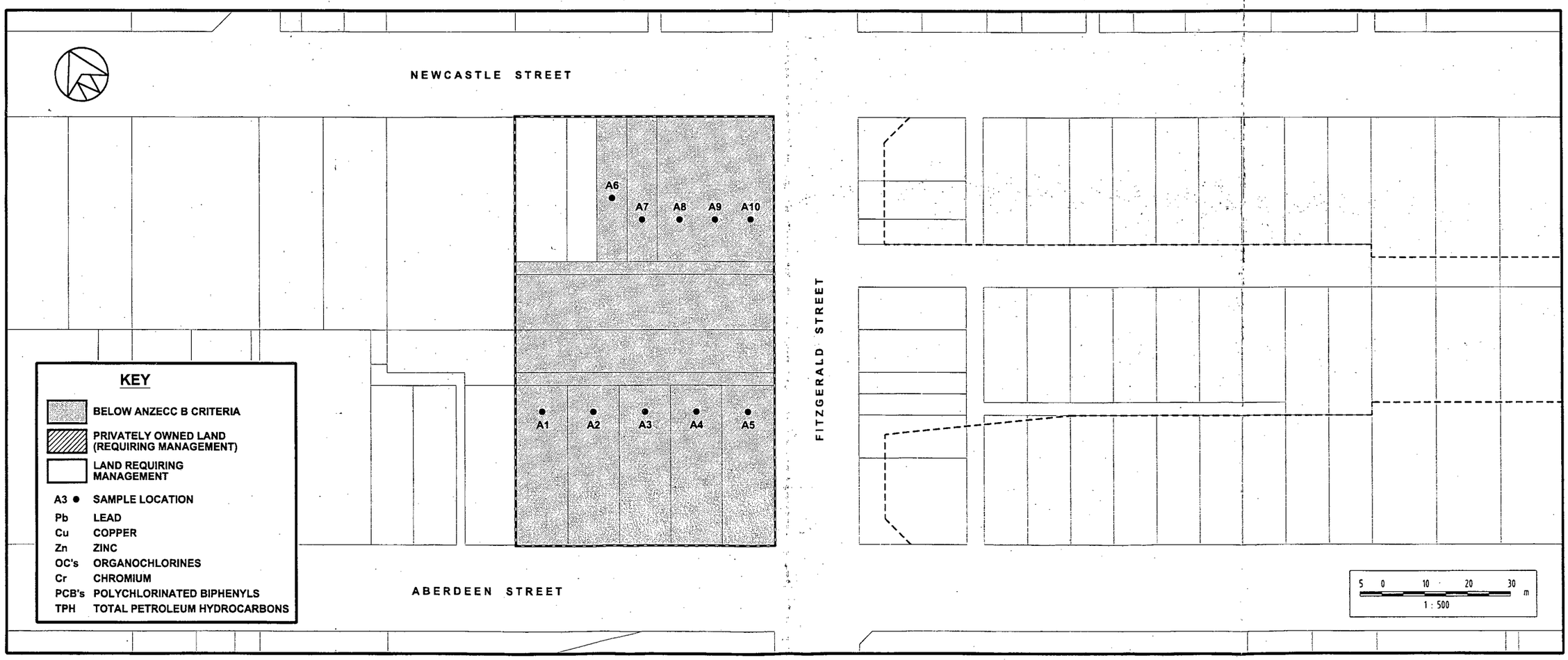

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

CLIENT
MINISTRY FOR PLANNING

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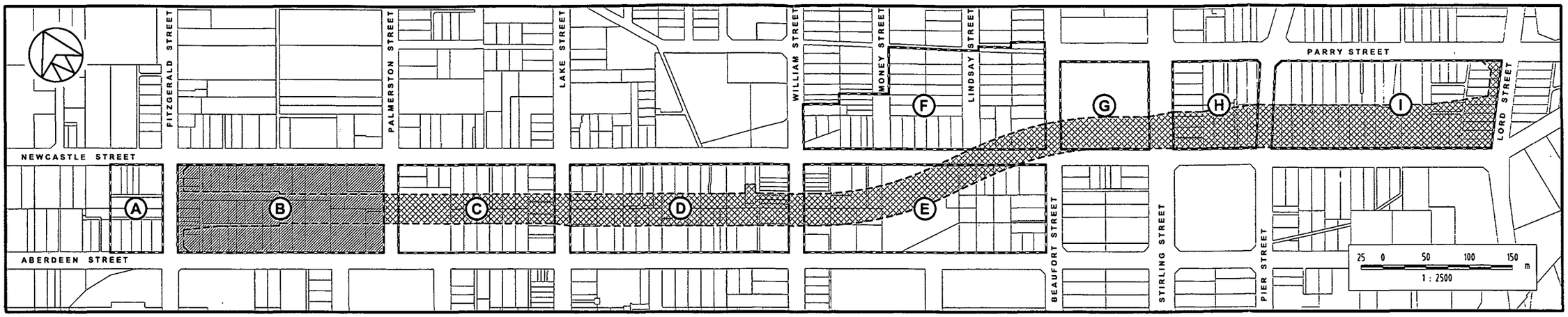
Fax : 61 9 325 9897
A.C.N. 000 912 630

TITLE
NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
MANAGEMENT STRATEGY
BLOCK A

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9A	OF	A

CAD FILE No 1216p301 PLOT INFO XREFS 14:47 26/08/99



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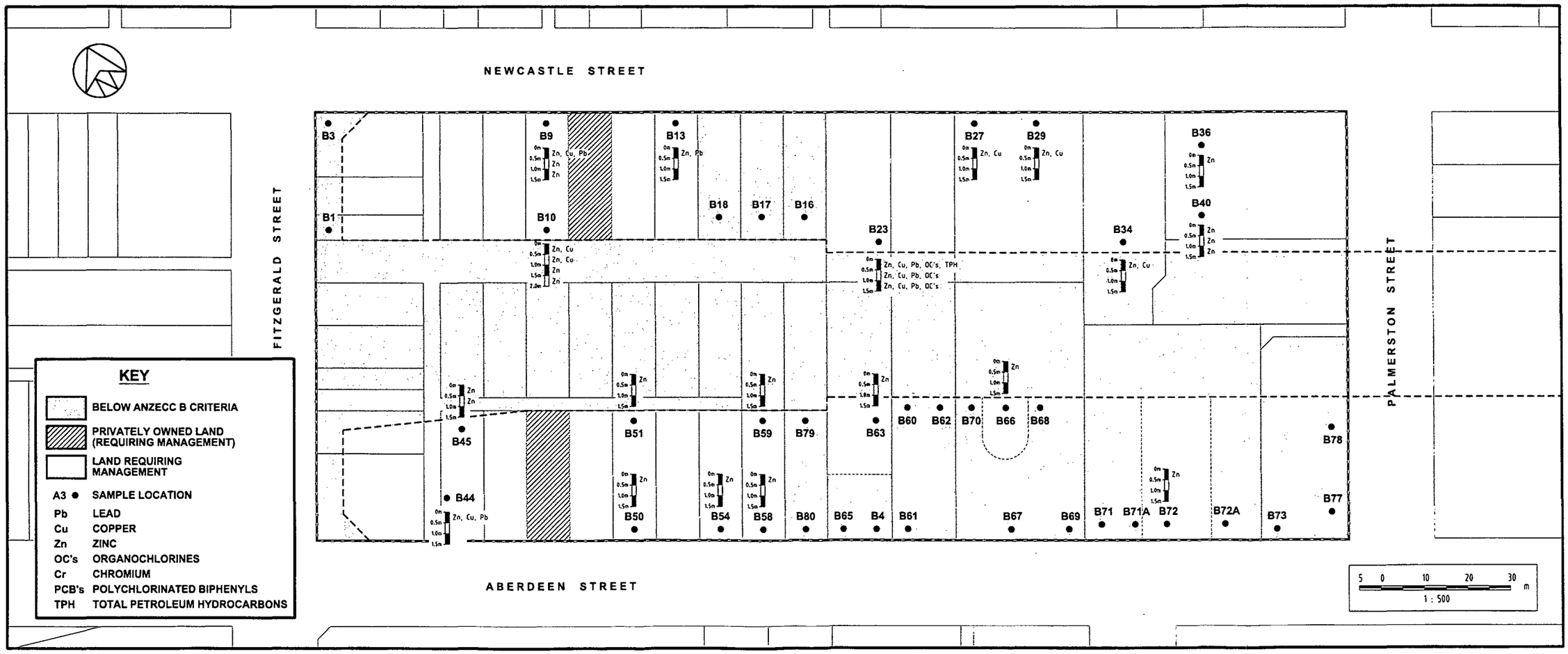

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DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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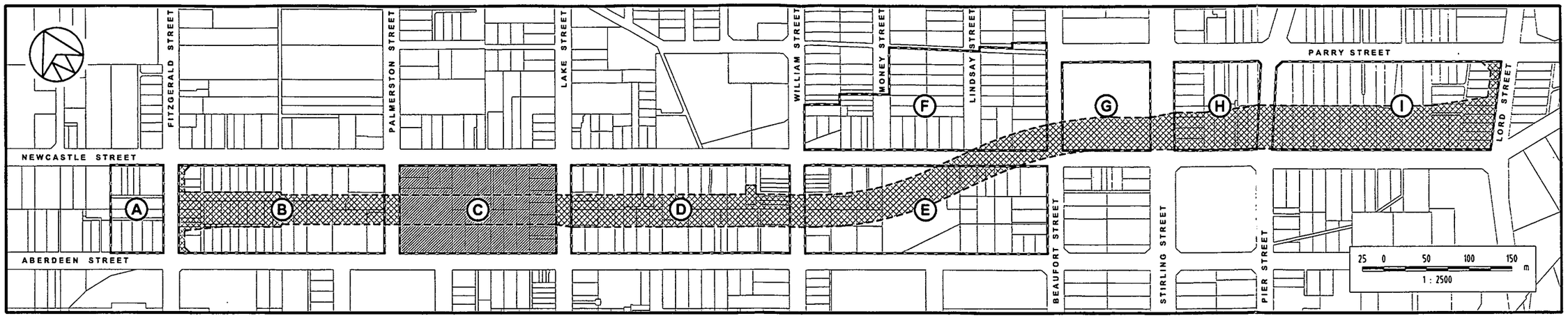
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
MANAGEMENT STRATEGY
BLOCK B

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9B	OF	A

CAD FILE No 1216p302 PLOT INFO XREFS 14:45 26/08/99



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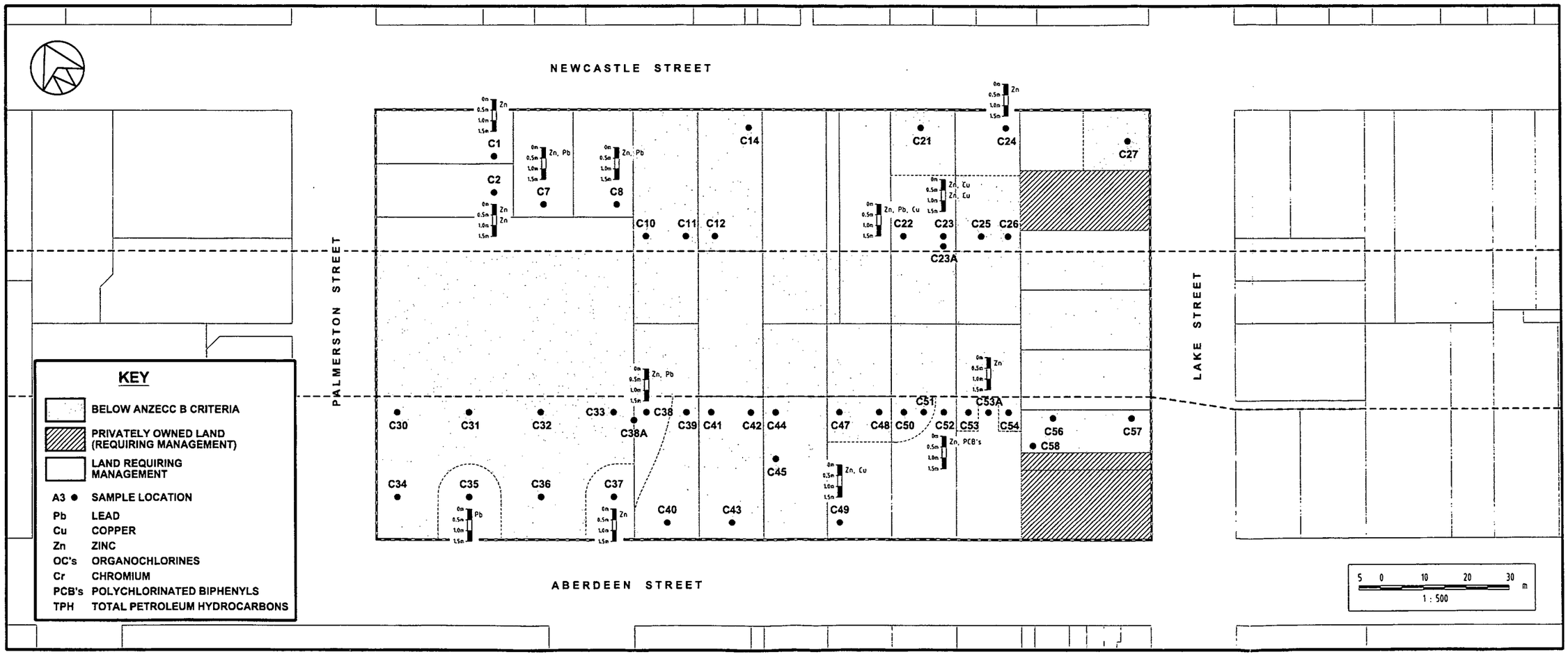

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SUPERVISOR			
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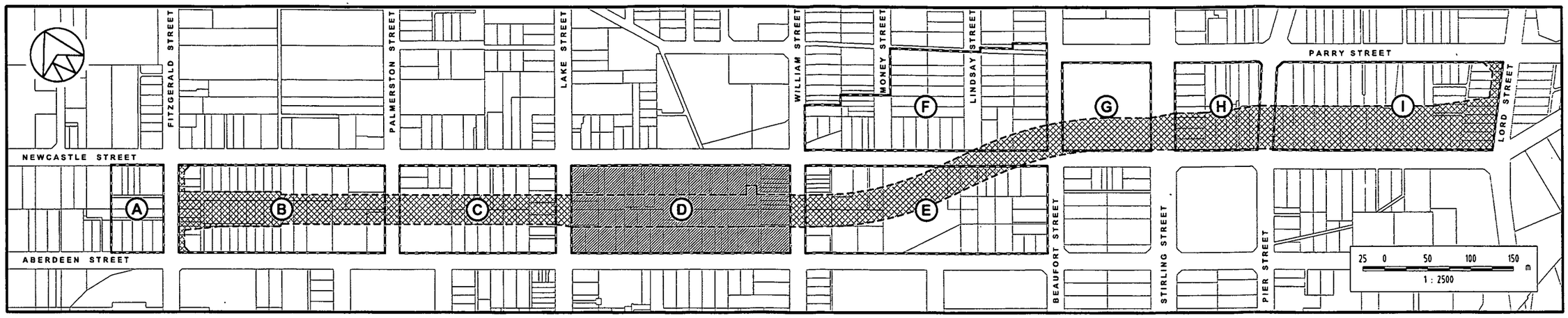
CAD FILE No 1216p303 | PLOT INFO XREFS 14:58 26/08/99

TITLE: NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION MANAGEMENT STRATEGY BLOCK C

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9C	OF	A



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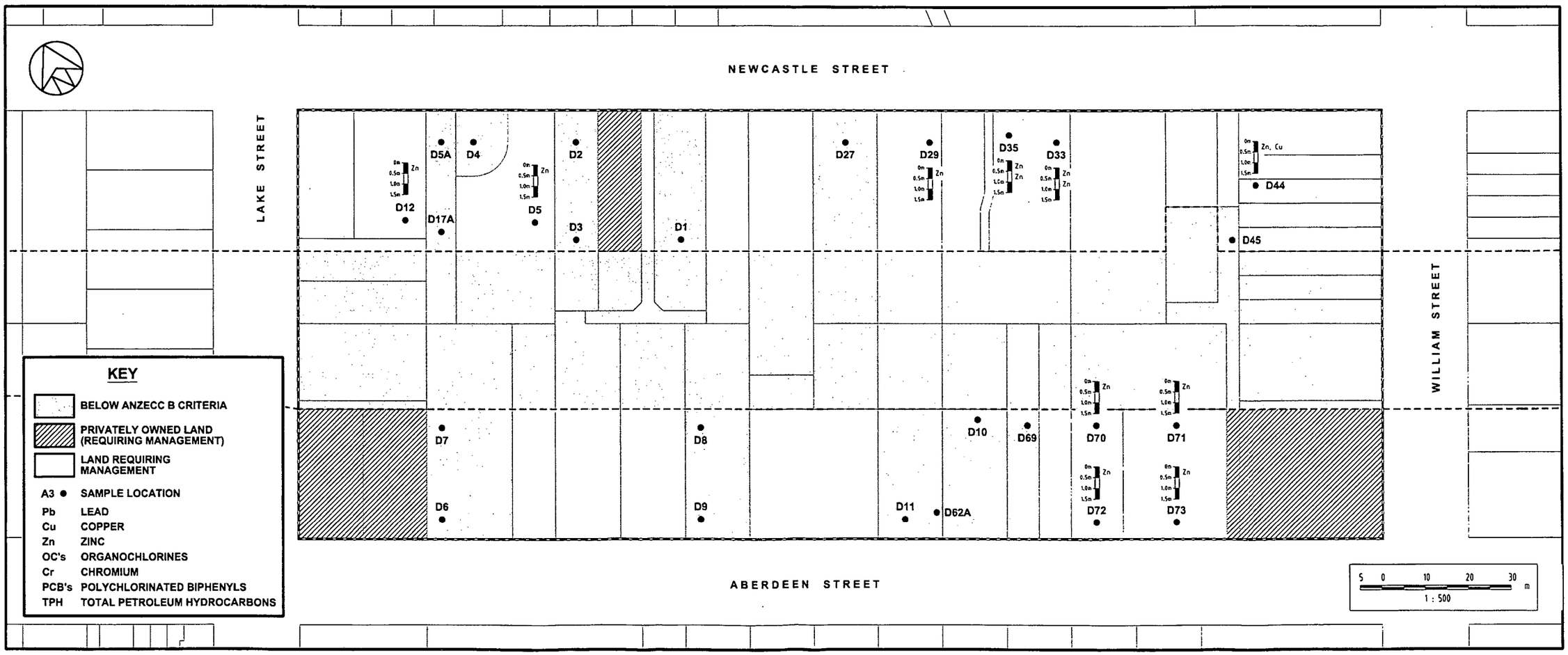

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	INITIALS	SIGNATURE	DATE
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DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
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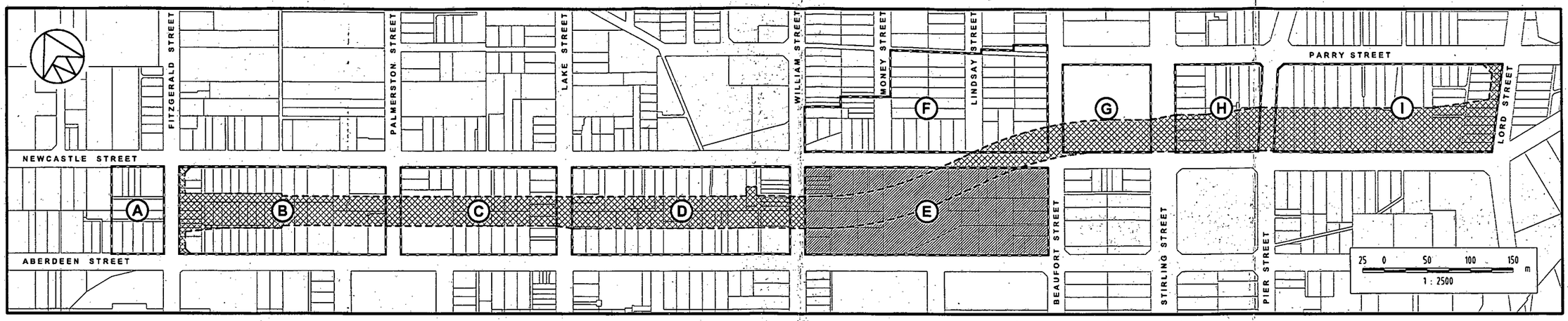
CAD FILE No 1216p304 | PLOT INFO XREFS 15:07 26/08/99

TITLE: NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION MANAGEMENT STRATEGY BLOCK D

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9D	OF	A



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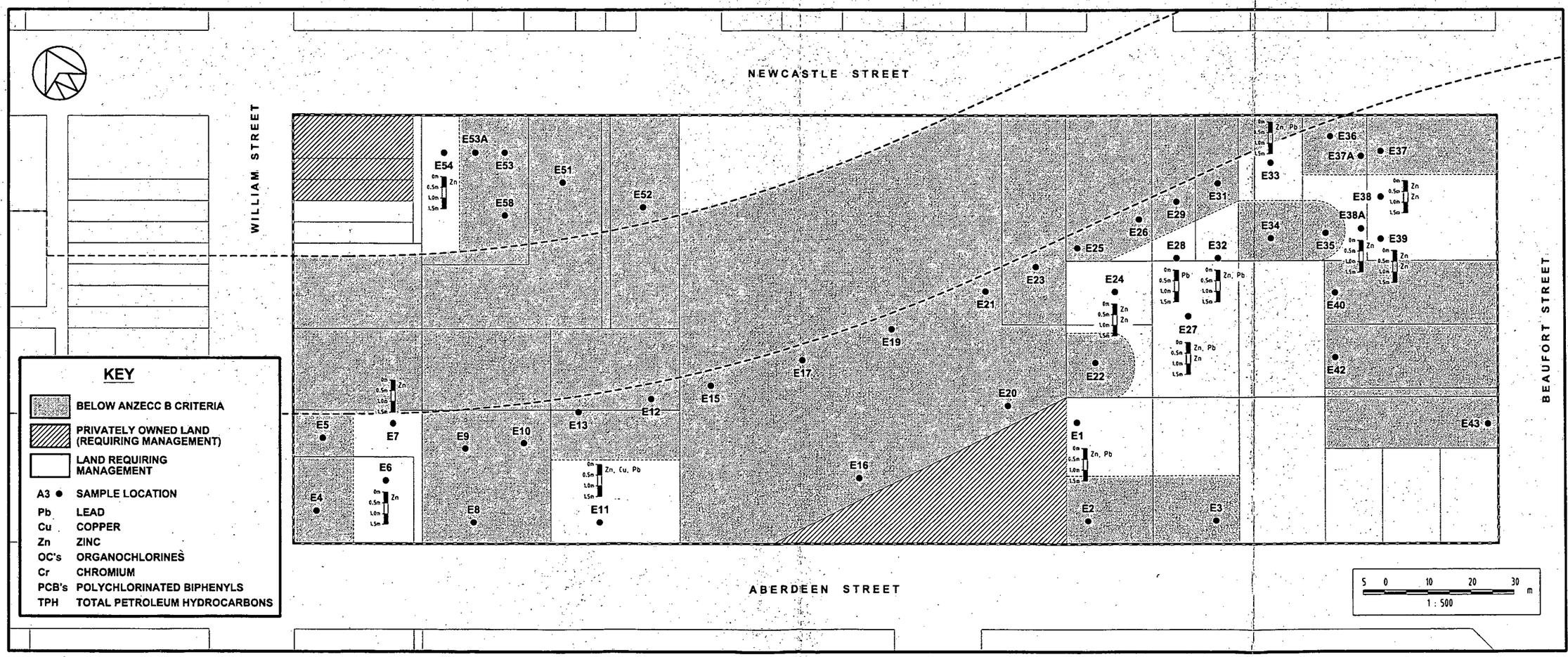

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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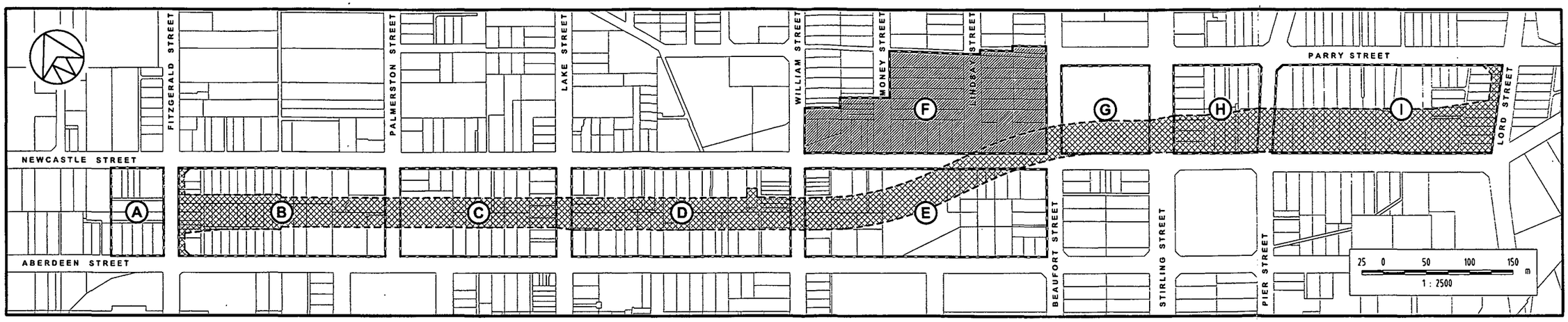
CAD FILE No 1216p305 | PLOT INFO XREFS 15:19 26/08/99

TITLE: NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION MANAGEMENT STRATEGY BLOCK E

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9E	OF	A



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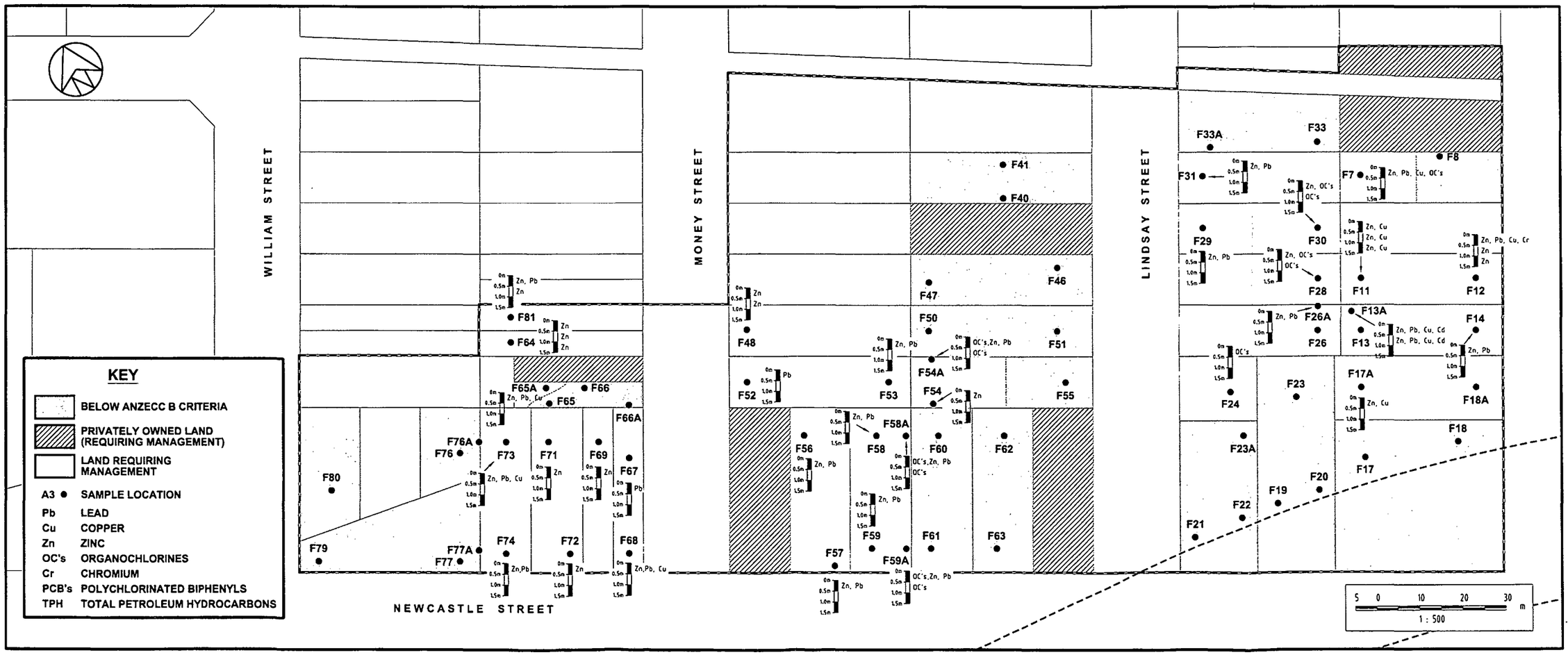

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DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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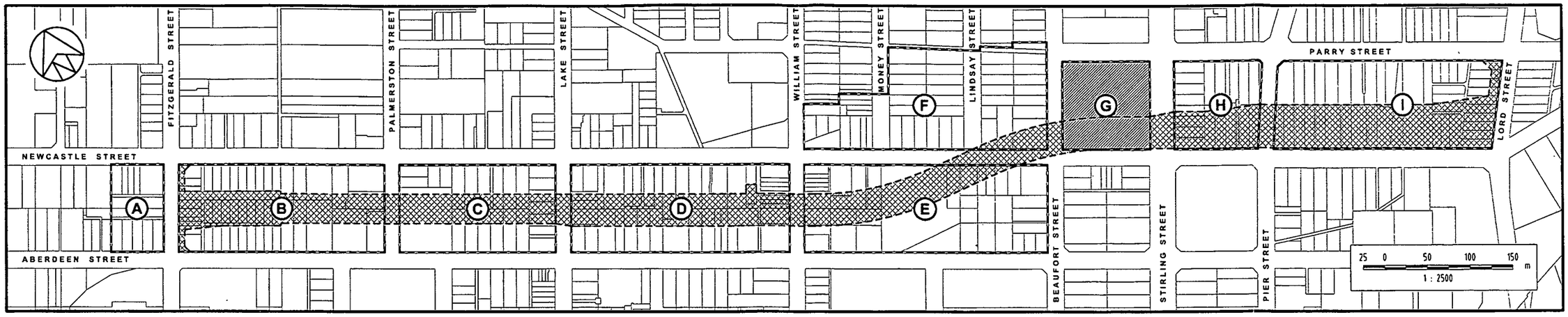
TITLE: NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION MANAGEMENT STRATEGY BLOCK F

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9F	0F	A

CAD FILE No 1216p306 | PLOT INFO XREFS 15:30 26/08/99



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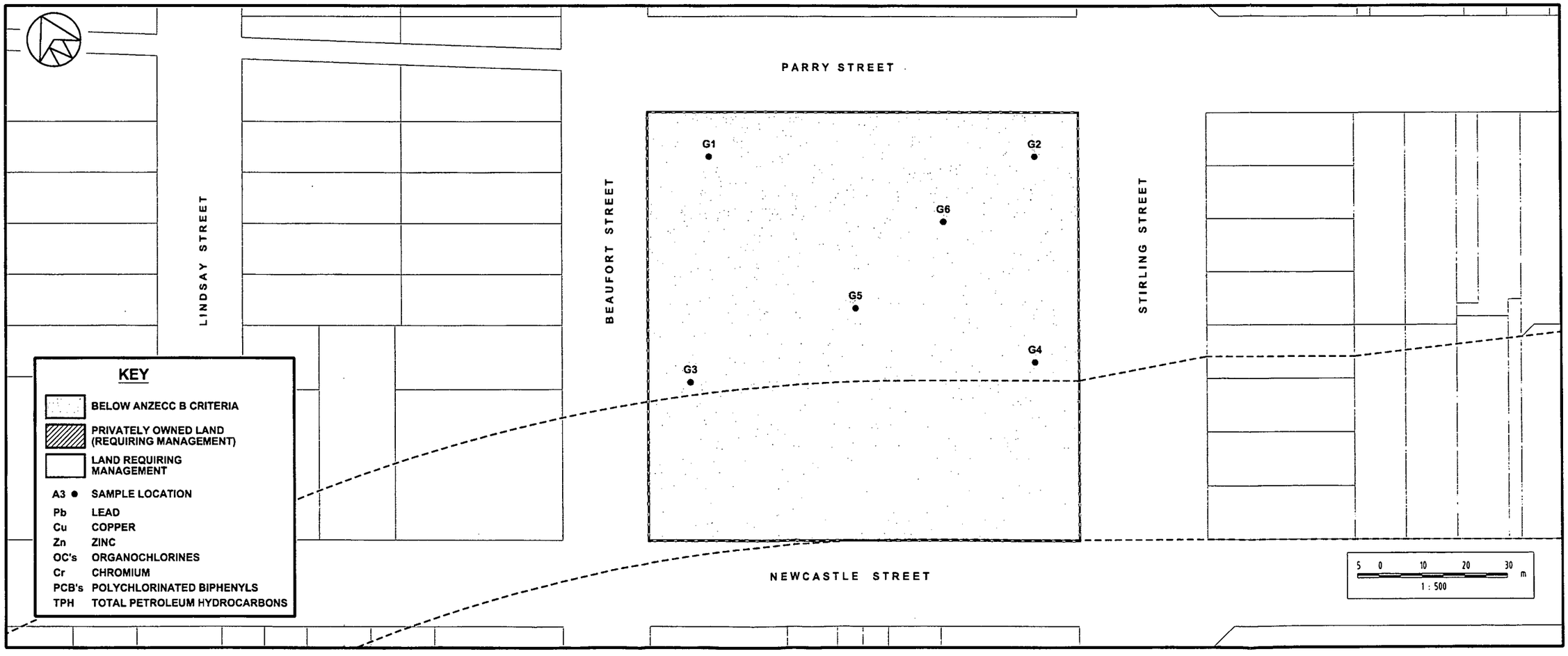

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	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

CLIENT: MINISTRY FOR PLANNING

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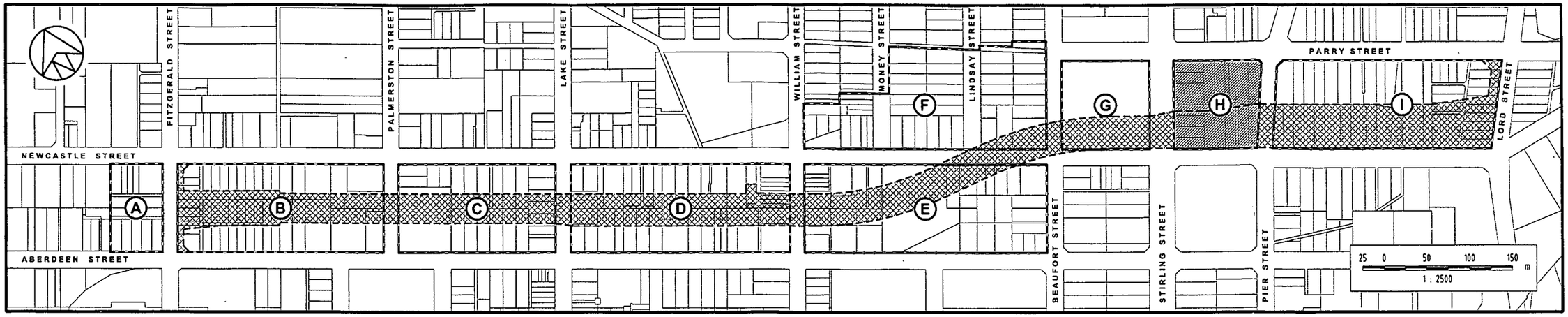
TITLE: NORTHBRIDGE URBAN RENEWAL
SOIL CONTAMINATION
MANAGEMENT STRATEGY
BLOCK G

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9G	OF	A

CAD FILE No 1216p307 | PLOT INFO XREFS 15:33 26/08/99



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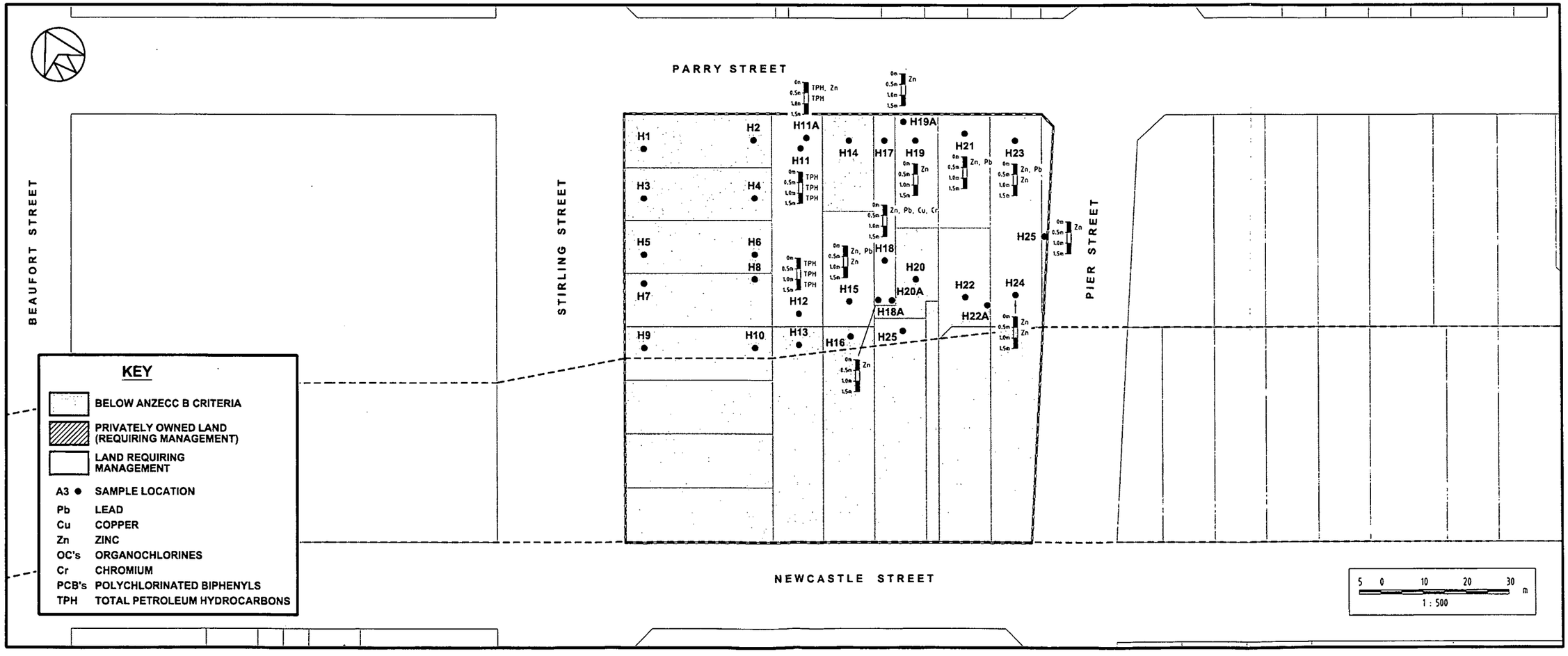

KEY

- BELOW ANZECC B CRITERIA
- PRIVATELY OWNED LAND (REQUIRING MANAGEMENT)
- LAND REQUIRING MANAGEMENT
- A3 ● SAMPLE LOCATION
- Pb LEAD
- Cu COPPER
- Zn ZINC
- OC's ORGANOCHLORINES
- Cr CHROMIUM
- PCB's POLYCHLORINATED BIPHENYLS
- TPH TOTAL PETROLEUM HYDROCARBONS

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
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	INITIALS	SIGNATURE	DATE
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DESIGNED	KD		
SUPERVISOR			
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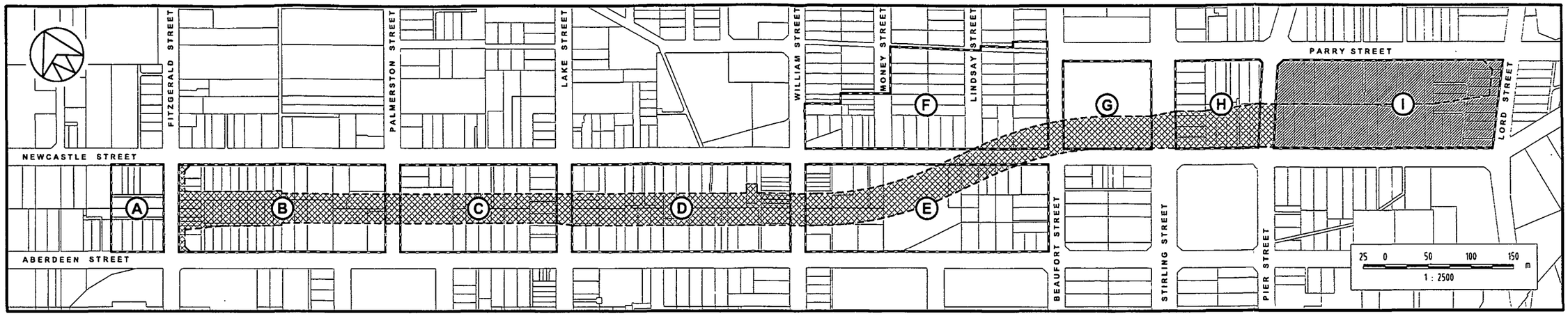
CAD FILE No 1216p308 | PLOT INFO XREFS 15:40 26/08/99

TITLE: NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION MANAGEMENT STRATEGY BLOCK H

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 9H	OF	A



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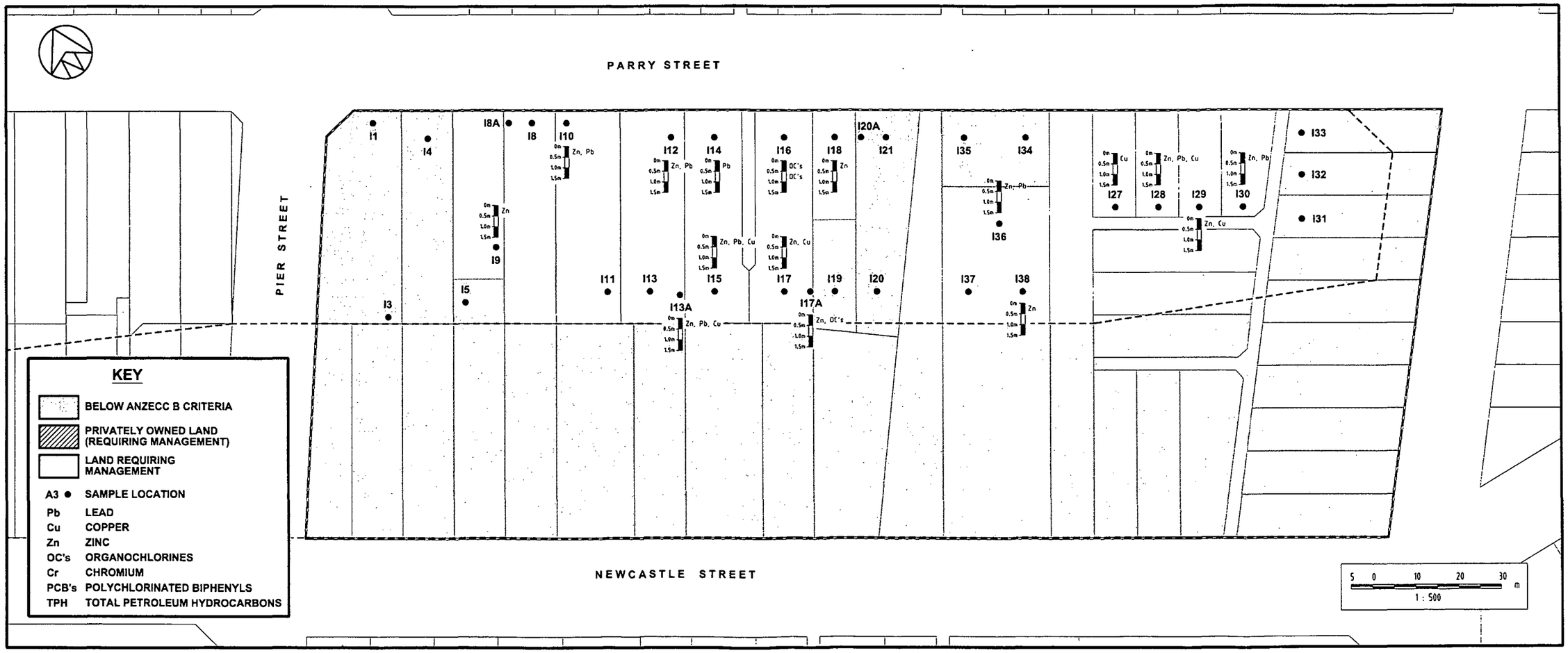

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DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

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TITLE: NORTHBRIDGE URBAN RENEWAL SOIL CONTAMINATION MANAGEMENT STRATEGY BLOCK 1

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 91	OF	A

CAD FILE No 1216p309 | PLOT INFO XREFS 15:49 26/08/99

APPENDIX A
EPA INSTRUCTIONS

2.5 Environmental factors relevant to the scheme

The EPA has identified some environmental factors which are relevant to the scheme area and should be addressed in the Environmental Review document. These factors are listed below (see Table 1).

Table 1: Environmental factors relevant to the scheme

CONTENT		SCOPE OF WORK		
Factors	**Site specific factor**	**Work required for the environmental review**	**Objective**	**Additional comments**
POLLUTION				
Land	Soil contamination	It is possible that some land within the area to be rezoned is effected by soil contamination. Show, through planning measures, how the amendment will ensure that: a) prior to development approval being granted for any land within the amendment area, a thorough investigation is made for the presence of soil contamination; b) the site investigation identifies the nature and extent of contamination; c) that a management strategy which details the remediation strategy, timing, disposal actions and validation program will be initiated in the event that soil contamination above levels agreed to by the Department of Environmental Protection is detected; and d) the site is cleaned up to the requirements of the Department of Environmental Protection.	Ensure the rehabilitation of the site to an acceptable standard that is compatible with the intended land use, consistent with appropriate criteria. Contaminated material should be treated on-site or disposed of off-site at an appropriate land fill facility. Where this is not feasible, contaminated material should be managed on-site to prevent groundwater contamination or risk to public health.	It is understood that any investigations for soil contamination will be undertaken at a later stage, prior to development of land contained within the amendment area.

2.6 Deferred environmental factors

- none identified at this stage (change as required)

APPENDIX B

ANALYTICAL RESULTS FOR PHASE I ENVIRONMENTAL SITE ASSESSMENT

1. BCJV SOIL ASSESSMENT OF TUNNEL ALIGNMENT

The soil sampling program was designed according to the historical potential for contamination. The purpose of the sampling program was to identify contamination in those areas destined to be excavated so that it could be separated from clean material which could be used as clean fill elsewhere. Soil contaminated above the ANZECC B environmental investigation level within the tunnel alignment corridor was removed separately to the clean fill and disposed to landfill.

Following the completion of the construction works, soil was reinstated over the tunnel by BCJV and a program of soil sampling was then implemented to validate the contamination status of the reinstated fill. This validation sampling program was undertaken by Egis Consulting in 1999, separate to the earlier BCJV soil assessment program.

The results of the tunnel alignment soil contamination assessment and the follow-up fill validation sampling program are discussed in the following subsections. Block A was not assessed as no soil was to be excavated as part of the tunnel project.

1.1 BLOCK B

A number of past industries were identified as potential sources of contaminants in Block B. The industries of concern included a pest control company, a radiator manufacturer, metal fabrication and metal treatment works. The soil sampling program was undertken on a surveyed 10m grid from which soil samples were taken to a depth of 1.5 m. A total of 72 soil samples were tested from Block B as part of the preliminary soil investigation.

Soil containing high concentrations of lead (up to 1,100 mg/kg) and zinc (up to 11,000 mg/kg) were detected to a depth of 2 m, this was excavated and disposed of to landfill. Zones of lower concentrations of contaminants in soil were also detected to 0.5m depth, with lead concentrations up to 620 mg/kg and zinc to 4,000 mg/kg. This contamination was also removed and disposed of to landfill. The HGM assessment report stated that all identified contamination in Block B were cleaned up as part of the construction program (HGM, 1998).

The validation sampling performed by Egis Consulting on the reinstated soil in Block B showed that the soil was clean and contained no contaminants in excess of normal background levels.

1.2 BLOCK C

The landuses within Block C included: metal fabrication, automotive, electrical and refrigeration industries. The soil sampling program was undertaken on a grid pattern apart from one property on which a house was still standing at the time of the investigation. A total of 45 soil samples were taken from Block C.

The assessment of contamination indicated levels of lead up to 1,500 mg/kg and zinc to 1,600 mg/kg. The contamination was shallow to a depth of 0.3 m and was excavated and disposed to landfill. The HGM assessment report noted that all soil contamination was removed as part of the tunnel construction program (HGM, 1998).

The soil validation program performed by Egis Consulting on Block C has shown that the soil reinstated over the tunnel construction does not contain contaminants over normal background levels.

1.3 BLOCK D

Previous landuses identified on Block D included automotive repair and drycleaning businesses. The soil sampling program was undertaken on a surveyed 10m grid. Some random sampling points were also used where a site inspection had identified areas of potential or visual contamination. A total 126 soil samples were taken from Block D.

Contamination with lead (up to 4,000 mg/kg) and zinc (up to 3,300 mg/kg) was detected to a depth of 0.75m. However, the contamination found did not appear to be specifically related to any previous landuse. All contamination was removed as part of the tunnel construction program (HGM, 1998).

The soil validation program performed by Egis Consulting on Block D indicate that clean fill reinstated over the tunnel construction area contains no contaminants above ANZECC B levels.

1.4 BLOCK E

The previous landuses on Block E were considered to have a minimal potential for soil contamination and therefore limited sampling was undertaken. Confirmation sampling was performed by taking 8 random soil samples from stockpiles of soil that had been excavated from the western portion of Block E. The eastern portion of Block E was not accessible at the time the assessment was performed.

Soil analysis indicated that there were no elevated levels of lead or zinc contaminants in the soil excavated from the western portion of Block E. The HGM assessment report (HGM, 1998) proposed that further testing be undertaken should visual observations suggest the presence of contamination.

The soil validation program performed by Egis Consulting on Block E has shown that the soil reinstated over the tunnel construction is clean with no contaminants above ANZECC B levels.

1.5 BLOCK F

Potential sources of contamination on Block F were identified as a galvanising industry, a furniture store and a plastics company. The HGM assessment report (HGM, 1998) states that no soil investigations were carried out on Block F at the time of printing.

Validation sampling performed by Egis Consulting on Block F indicate that clean fill reinstated over the tunnel construction area contains no contaminants above ANZECC B levels.

1.6 BLOCK G

Historical investigations found that the landuse on Block G was limited to residential and parkland, therefore no physical soil sampling and assessment was performed (HGM, 1998).

The results of the validation program performed by Egis Consulting indicate that the clean fill reinstated over the tunnel construction area contains no contaminants above ANZECC B levels.

1.7 BLOCK H

A historical study of the land in Block H and site inspection indicated that several lots were occupied by automotive repair shops and car hire firms. It was

determined that these businesses could be a possible source of hydrocarbon contamination and that a sampling grid of 10m by 20m was therefore initiated.

A total of 42 soil samples were routinely tested for lead and zinc with a selection of samples also tested for arsenic, cadmium, copper and mercury.

Nine locations were identified as contaminated with heavy metals to levels above the ANZECC B investigation level with concentrations of lead detected up to 600 mg/kg and levels of zinc up to 330 mg/kg. Contamination was detected in soil in several areas to a depth of 0.75m.

The preliminary soil contamination assessment report (HGM, 1998) suggests that four lots (Lots 1, 2, 6 and Pt W40) may contain levels of contaminants that require excavation and disposal at landfill. The HGM report indicates that soil contamination identified during the tunnel construction works would be cleaned up as part of the project.

The validation program performed by Egis Consulting has shown that clean fill reinstated over the tunnel construction does not contain contaminant levels above ANZECC B levels.

1.8 BLOCK I

The historical studies performed on land in Block I identified several landuses that had a potential to create soil contamination. One of these landuses was an automotive repair business. The site investigation was performed by soil sampling on a 10m by 20m grid to a depth of 1m. All samples to 0.5m depth were tested for lead and zinc with 8 random samples also tested for arsenic, cadmium, copper and mercury. In total, 92 soil samples were submitted for laboratory analysis from Block I.

Twenty locations in Block I were identified as contaminated with heavy metals above the ANZECC investigation level with concentrations of lead detected up to 990 mg/kg and levels of zinc up to 700 mg/kg.

The preliminary soil contamination assessment report (HGM,1998) noted that contamination in one area appeared to be associated with a band of dark coloured material observed at a depth between 0.5 m and 0.85 m. This discoloured soil was excavated and disposed to landfill. Another area of contaminated soil in Block I, where lower concentrations of metal contaminants were detected to a depth of 0.5m was also removed during excavation in the tunnel work area.

The validation program performed by Egis Consulting has shown that clean fill reinstated over the tunnel construction does not contain contaminant levels above ANZECC B levels.

2. SOIL CONTAMINATION STATUS OUTSIDE OF TUNNEL ALIGNMENT

The following sections summarise the level and extent of contamination identified in each Block. The criteria used to assess the contamination is based on the ANZECC B environmental investigation level and 1998 NEHF Health based investigation levels (HIL) for a standard residential setting. Areas nominated in the text exclude the tunnel alignment.

2.1 BLOCK A

The area of block A is about 0.6 ha. The assessment of contamination in Block A has been based on 10 sampling locations to a depth of 1.5 m. No contaminants above either ANZECC B or the HIL were detected.

Results are summarised in Table A.

TABLE A
BLOCK A SUMMARY

Number of lots in Block A	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants
10	8	10	10	None

2.2 BLOCK B

The area of block B is about 1.46 ha. The assessment of contamination in Block B has been based on 41 sampling locations. A large number of commercial and residential buildings and hardstand surfaces limited the number of lots that could be accessed. One third of the lots were not sampled for these reasons.

Soil samples from 19 of the 41 sampling locations exceeded ANZECC B levels. Of these, 14 contained concentrations of heavy metals above the environmental assesment criteria in the surface to 0.5 m sample only. The main heavy metal at these locations was zinc, with some copper and lead contamination also identified.

Contamination in soils below 0.5 m depth was identified at five locations. Of these, three locations had concentrations of zinc above the ANZECC B level with one location also exhibiting zinc and copper concentrations above ANZECC B.

One location (B23) was found to contain heavy metal, hydrocarbon and OC contamination to a depth of 1.5 m. A maximum lead concentration of 3,400 mg/kg was identified in the surface to 0.5 m sample. This value is 17 times greater than the HIL and ANZECC B level of 300 mg/kg. Samples below 1.5 m depth were not able to be recovered. This sample location is adjacent to an existing radiator business.

The 19 locations in which contamination was detected is distributed over 13 lots. Three of these lots have been identified as the location of a previous or current potentially contaminating landuse. An additional 6 lots back onto a previous contaminating landuse.

Results are summarised in Table B overleaf.

TABLE B
BLOCK B SUMMARY

Number of lots in Block B	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HIL	ANZECC B	HIL	(mg/kg)
33	21	41	22	Copper	7	0	60	1,000	240
				Lead	4	4	300	300	3,400
				Zinc	19	0	200	7,000	950
				Dieldrin	1	0	0.2	10	0.5
				TPH (C_6-C_9)	1	TBA	100*	NC	820

*Dutch B Criteria applies

NC No criteria established

TBA To be assessed.

2.3 BLOCK C

The area of block C is about 1.19 ha. The assessment of contamination in Block C has been based on 45 sampling locations. A large number of commercial and residential buildings plus hardstand surfaces limited the number of lots that could be accessed. However, almost 80% of lots were able to be sampled.

Heavy metal concentrations in soil samples from 13 locations exceeded ANZECC B levels. Of these, 11 contained concentrations of heavy metals above the environmental criteria in the surface to 0.5 m depth sample. Heavy metal contamination was identified in the 0.5m to 1.0 m sample at only two of the 11 locations. The principal heavy metal contaminant at these locations was zinc, with some elevated concentrations of copper and lead.

PCB's were detected in the surface to 0.5 m sample at location C52. Adjacent samples and samples from the 0.5 m to 1.0 m depth interval exhibited no detectable concentrations of PCB's, thus suggesting the contamination is localised. An electrical business occupies the lot on which the sample was taken. The lot to the east was previously used for metal fabrication.

The 13 locations in which contamination was identified are distributed over 11 lots. Four of these lots have been identified as the location of a previous or current potentially contaminating landuse.

Results are summarised in Table C overleaf.

TABLE C
BLOCK C SUMMARY

Number of lots in Block C	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HIL	ANZECC B	HIL	(mg/kg)
23	18	45	32	Copper	3	0	60	1,000	130
				Lead	5	5	300	300	630
				Zinc	12	0	200	7,000	880
				PCB's	1	0	1	10	4

2.4 BLOCK D

The area of block D is about 1.58 ha. The assessment of contamination in Block D has been based on 26 sampling locations. A large number of commercial and residential buildings plus hardstand surfaces limited the number of lots that could be accessed. Approximately half of the lots were sampled.

Soil samples from 10 of the sampling locations exceeded ANZECC B levels. Of these locations, seven contained zinc contamination with one location exhibiting copper and zinc contamination in the surface half metre. Two locations on the same lot contained zinc contamination in the surface to 0.5 m and 0.5 to 1.0 m depth samples. Samples below 1.0 m depth could not be recovered at these locations.

The 10 locations in which contamination was identified are distributed over seven lots. Two of these lots have been identified as the location of a previous or current potentially contaminating landuse.

Results are summarised in Table D overleaf.

TABLE D
BLOCK D SUMMARY

Number of lots in Block D	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HIL	ANZECC B	HIL	(mg/kg)
36	17	26	16	Copper	1	0	60	1,000	220
				Zinc	10	0	200	7,000	2,100

2.5 BLOCK E

The area of block E is about 2.04 ha. The assessment of contamination in Block E has been based on 47 sampling locations. A few of the smaller lots could not be accessed. The remainder of the block is asphalt covered carpark. Sampling access was achieved through existing holes in the asphalt which may have potentially concentrated any contamination resulting from spillage.

Soil samples from 12 of the sampling locations exceeded ANZECC B levels. Of these, nine contained concentrations of heavy metals above ANZECC B in the surface to 0.5 m depth interval. The primary heavy metals at these locations were zinc and lead with one location also containing elevated copper concentrations. Zinc contamination was identified in the 0.5 m to 1.0 m sample at three locations.

The 12 locations in which contamination was identified are distributed over 11 lots. Two of these lots have been identified as the location of a previous or current potentially contaminating landuse.

Results are summarised in Table E overleaf.

TABLE E
BLOCK E SUMMARY

Number of lots in Block E	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HIL	ANZECC B	HIL	(mg/kg)
35	25	47	35	Copper	1	0	60	1,000	410
				Lead	6	6	300	300	780
				Zinc	11	0	200	7,000	670

2.6 BLOCK F

The area of block F is about 2.54 ha. The assessment of contamination in Block F has been based on 67 sampling locations. Approximately 70% of lots were accessed. Areas of buildings and hardstand, particularly on Money Street, limited the number of lots that could be accessed. Five lots are privately owned and were therefore not tested.

Soil samples from 34 of the sampling locations exceeded ANZECC B levels. Of these, 27 contained heavy metals above ANZECC B in the surface to 0.5 m depth interval. Heavy metal contamination was found in the 0.5m to 1.0 m samples at three locations, and in the 1.0 m to 1.5 m samples in three additional locations. The principal heavy metal contaminant at these locations was zinc copper and lead. Cadmium and chromium was also detected. OC contamination was identified at seven locations.

The 34 locations in which contamination was identified are distributed over 22 lots. Four of these lots have been identified as the location of a previous or current potentially contaminating landuse.

Results are summarised in Table F overleaf.

TABLE F
BLOCK F SUMMARY

Number of lots in Block F	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HIL	ANZECC B	HIL	(mg/kg)
48	34	67	33	Cadmium	1	0	3	20	3.7
				Chromium	1	0	50	12%/100**	100
				Copper	8	0	60	1,000	150
				Lead	22	22	300	300	3,000
				Zinc	30	0	200	7,000	1500
				Dieldrin	8	0	0.2	10	0.5

Note **12% Cr(III), 100 Cr(VI)

2.7 BLOCK G

The area of block G is about 0.64 ha. The assessment of contamination in Block G has been based on six sampling locations. Block G (Weld Square) has historically been a park or open space with no history of contaminating activities. No contaminants above ANZECC B levels were detected.

Results are summarised in Table G.

TABLE G
BLOCK G SUMMARY

Number of lots in Block G	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified
1	1	6	6	None

2.8 BLOCK H

The area of block H is about 0.54 ha. The assessment of contamination in Block H has been based on 31 sampling locations. Samples were obtained from all lots within Block H.

Soil samples from 10 of the sampling locations exceeded ANZECC B levels for heavy metals. Of these, 7 contained heavy metals above ANZECC B in the surface to 0.5 m depth interval. Three contained heavy metal contamination to 1.0 m depth. The principal heavy metal at these locations is zinc and lead. Copper and chromium was also detected.

Three samples obtained from the same lot (H11, H11A and H12) contained hydrocarbon contamination to a depth of 1.5 m. Samples beyond this depth were not able to be recovered.

None of the blocks where contamination was identified are directly associated with an existing or previous contaminating landuse. However the lot on which hydrocarbon contamination was identified borders onto lots previously used as a car yard and car repairs workshop.

Results are summarised in Table H overleaf.

TABLE H
BLOCK H SUMMARY

Number of lots in Block H	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HIL	ANZECC B	HIL	(mg/kg)
15	15	31	19	Chromium	1	0	50	12% / 100**	53
				Copper	1	0	60	1,000	73
				Lead	4	4	300	300	430
				Zinc	10	0	200	7,000	4,400
				TPH (C_{10}-C_{36})	3	0	100*	5,600	12,500

Dutch B Criteria

Note ** 12% Cr(III), 100 Cr(VI)

2.9 BLOCK I

The area of block I is about 1.20 ha. The assessment of contamination in Block I has been based on 34 sampling locations. Samples were obtained form all but two lots.

Soil samples from 15 of the sampling locations exceeded ANZECC B levels for heavy metals. All heavy metal contamination was confined to the surface to 0.5 m depth interval. The heavy metals identified at these locations were zinc, lead and copper. OC's were identified in samples from two locations slightly above ANZECC B.

The 16 locations in which contamination was identified are distributed over 11 lots. One of these lots has been identified as the location of a previous or current potentially contaminating landuse.

Results are summarised in Table I overleaf.

TABLE I
BLOCK I SUMMARY

Number of lots in Block H	Number of lots sampled	Number of sampling locations	Number of uncontaminated locations	Contaminants identified	Number of sampling locations where contamination was identified		Criteria values		Maximum contaminant concentrations
					>ANZECC B	>HBL	ANZECC B	HBL	(mg/kg)
22	18	34	18	Copper	6	0	60	1,000	270
				Lead	8	8	300	300	1,000
				Zinc	13	0	200	7,000	1,000
				Dieldrin	3	0	0.2	10	1.3

APPENDIX C
QUALITY ASSURANCE PROGRAM

APPENDIX C
QUALITY ASSURANCE PROGRAM

Environmental sampling requires specific sampling techniques and a high level of quality control. Sampling protocols ensure that the samples submitted for laboratory analysis have been sampled in the appropriate manner and are truly representative of the conditions. Quality control includes laboratory reanalysis of a number of samples and decontamination procedures for sampling equipment to ensure there has been no cross contamination between sample locations.

Soil samples were taken in accordance with an appropriate quality assurance plan which details the methods of sampling, handling and transport of samples and decontamination or cleaning procedures for sampling equipment.

All samples were analysed at quality controlled NATA (National Association of Testing Authorities) registered laboratories. Samples were transported in cooled, insulated containers and were analysed within their appropriate holding times.

The quality assurance procedures involved with the two major investigations (HGM, 1998 & Egis, 1999) which are used to characterise the nature and extent of contamination are outlined as follows:

- *HGM, 1998*: all equipment used for sampling of soil was decontaminated before and after use.

- *Egis, 1999*: all equipment used for soil sampling was decontaminated before and after use with a detergent solution and clean water rinse. Duplicate samples of soil were performed including secondary laboratory checks. Duplicate and triplicate samples were collected every twenty sampling locations.

APPENDIX D
HEALTH RISK ASSESSMENT

egis consulting
Australia

DOCUMENT NO:VW1216/200RP-00-004

REPORT FOR

HEALTH RISK ASSESSMENT

FOR

NORTHBRIDGE TUNNEL REDEVLOPMENT

Client: EAST PERTH REDEVELOPMENT AUTHORITY

Report: VW1216/200 – RP-00-004

Dated: JUNE 1999

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EXECUTIVE SUMMARY

The State Government through Main Roads and the Western Australian Planning Commission has substantial land holdings in Northbridge adjacent to and including the tunnel alignment which are to be redeveloped for high density residential, commercial and entertainment purposes. In order to redevelop the land for residential purposes, the contamination status of the soil has been assessed in accordance with the Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for the Assessment and Management of Contaminated Sites (1992),, to determine suitability and the need for any remediation.

A health risk assessment has then been undertaken to evaluate the risks to human health posed by the soil contamination identified in the environmental investigations. The risk to future residents is considered to be from exposure to lead and volatile hydrocarbon contaminated soil.

The health risk assessment considered dermal contact, ingestion and inhalation exposure pathways. The risk was assessed against maximum contaminant levels so as to reduce the chance of underestimating potential exposure levels.

The response levels for lead and heavy fraction hydrocarbons is taken from the NEHF health investigation levels which are shown on Table 3. A commercial setting (NEHF Exposure Setting F) has also been included for reference purposes.

TABLE 3
PROPOSED RESPONSE LEVELS

All results expressed as milligrams per kilogram

CONTAMINANT	RESIDENTIAL EXPOSURE SETTING A	HIGH DENSITY RESIDENTIAL EXPOSURE SETTING D	PARKS/OPEN SPACE EXPOSURE SETTING E	COMMERCIAL EXPOSURE SETTING F
Lead	300	1,200	600	1,500
Heavy Fraction Aliphatic TPH	5,600	22,400	11,200	28,000

1. BACKGROUND TO THE HEALTH RISK ASSESSMENT ISSUE

1.1 INTRODUCTION

The State Government through Main Roads and the Western Australian Planning Commission has substantial land holdings in Northbridge. The land was acquired for the construction of the Northbridge Tunnel. This land is to be redeveloped for residential, commercial and entertainment purposes and is termed: *The Northbridge Redevelopment Area or NRA.*

The Northbridge Redevelopment Area (NRA) is a narrow corridor of land running east of Fitzgerald Street towards Lord Street. The area is bounded by Aberdeen Street to the south and Newcastle Street to the north along the western sector. East of Beaufort Street, the area extends northward and is bounded by Newcastle Street to the south and Parry Street to the north (Figure 1).

The current landuse within the NRA is a mix of residential and commercial. Commercial landuse is focused along the western half of the redevelopment area with residential landuse primarily in the eastern part. Past landuses have resulted in parts of the NRA land having soil contamination. The contamination status of the NRA is provided in detail in the Environmental Review and is summarised in Section 2.

The majority of properties within the NRA are in government ownership, mostly with the Western Australian Planning Commission (WAPC) who is the proponent for the redevelopment. Twenty properties in the redevelopment area are privately owned and have not been investigated, the contamination status of which is unknown. The land above the Northbridge tunnel is presently cleared and has been constructed of clean fill.

1.2 PURPOSE OF THE HEALTH RISK ASSESSMENT

In order to redevelop the land for residential purposes, the contamination status of soils must be assessed to determine suitability and the need for any remediation. The NRA has been subject to a number of site investigations which have found generally low level superficial soil contamination. The results of the assessment phase are subject to a Health Risk Assessment (HRA) which will be used to evaluate the risks to human health posed by the soil contamination. The HRA process is described in detail in Section 2.

The objective of the HRA is to consider and assess any potential risks related to future residents or occupiers of sites within the NRA. The results of the HRA will be used to determine those sites that require remediation prior to redevelopment.

Groundwater use is not expected due to the proposed densities of the redevelopment which are up to R160. Thus the contamination status of the underlying groundwater has not been considered.

The protection of the health of workers engaged in the removal of contaminated materials is outside the scope of this document. This issue will be addressed by the remediation contractor at a later date as part of their occupational health and safety management plan.

2. THE HEALTH RISK ASSESSMENT PROCESS

2.1 GENERAL

Health Risk Assessment (HRA) is commonly used to assess the health impacts associated with contaminated soil and groundwater. This process allows for the development of site-specific risk-based criteria which can be applied as response levels for remedial works (ie clean-up criteria for remediation or levels requiring management action).

HRA is a primary component in an overall risk-based approach to decision making which seeks to manage risk to human health and facilitate redevelopment of contaminated land. Determining the level of risk of an adverse effect on human health uses a structured and well-recognised process outlined in the Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for the Assessment and Management of Contaminated Sites (1992).

The principal components of this process are:

- hazard identification;
- exposure assessment;
- toxicity evaluation;
- risk characterisation.

The Health Risk Assessment process is illustrated on Figure 2.

An important tenet of HRA is that the underlying objective is to effectively protect the most sensitive individuals in the exposed population (for example children or the elderly). In sufficiently protecting the more sensitive receptor groups in the population it is assumed that the general population is protected. This objective is evidenced in the commonly adopted levels of acceptable incremental risk of cancer used in decision making; usually in the range 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) per lifetime (i.e. one additional case of cancer in 10,000 to 1,000,000 people).

HRA seeks to determine the intake of a chemical by an individual and how this level compares to a nominal dose that is considered acceptable. With respect to soil contamination, exposure may arise from a range of routes, including ingestion of soil, inhalation of volatiles or particulates, dermal absorption and food chain exposure. Exposure to contaminated groundwater may arise from consumption, direct contact with waterbodies, irrigation and exposure via the food chain.

In assessing possible adverse effects on human health, consideration is given to a range of carcinogenic and non-carcinogenic effects. It is often the carcinogenic effects that are limiting in terms of possible adverse effects.

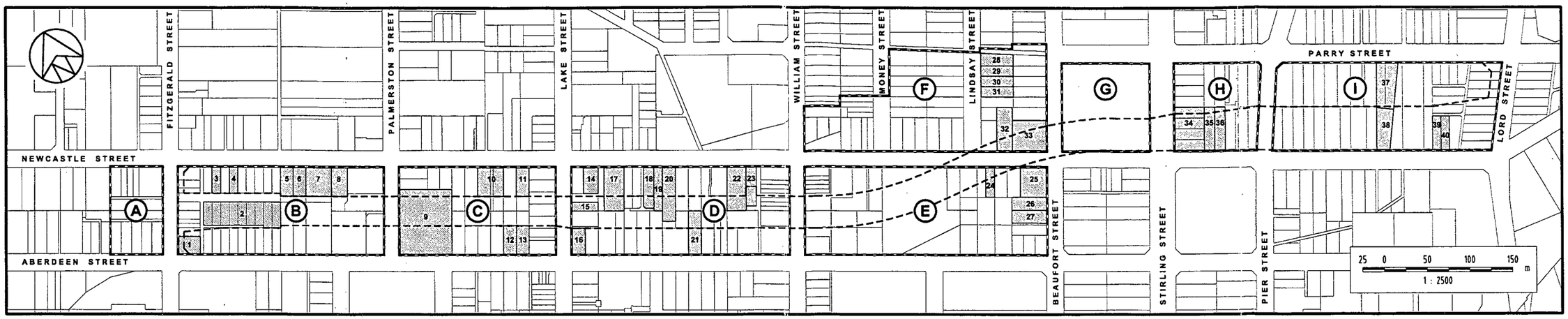
2.1.1 Risk Assessment Process

Health risk assessment is primarily used to determine the risk posed to human health rather than the environment. Firstly, the nature and extent of contamination is determined by an Environmental Site Assessment (ESA). Analytical results are compared to Tier 1 criteria which normally comprise both environmental and human health investigation levels. Where Tier 1 criteria is exceeded, a site specific or Tier 2 risk assessment maybe undertaken. The results of the Tier 2 assessment then determine the need for management or remediation of the contamination.

Risk assessment can be performed either in a forward or back calculation mode. Forward risk assessment is where the current contamination status is considered acceptable to remain based on site specific factors. Back calculation is where the level of acceptable risk is first determined and then a response or clean-up level is calculated based on site specific factors.

For the NRA, this risk assessment process will be forward and will be based on maximum observed contaminant levels. This approach has been undertaken due to the large size of the proposed project and on the frequency of testing performed as part of the initial soil sampling program.

As the ESA was a Phase 1 investigation, the scope of works was to determine what the contaminants of concern are rather than full delineation of the extent of impact. Therefore conservatism must be applied to the results to ensure the worst case scenario is considered in the HRA process.



1 METAL MERCHANT
2 GALVANISING FACTORY
3 AUTO BUSINESS
4 PEST CONTROL FACTORY
5 RADIATOR FACTORY
6 SPRAY PAINTER
7 AUTO BUSINESS
8 AUTO BUSINESS
9 METAL FABRICATION
10 VEHICLE SERVICING
11 DRIVING SCHOOL
12 ELECTRICAL BUSINESS
13 METAL FABRICATION
14 AUTO BUSINESS
15 BITUMEN PRODUCTS
16 BAKERY
17 FACTORY
18 SPRAY PAINTING
19 MOTOR BODY BUILDING WORKS AND REPAIR SHOP / DEPOT FOR DRY CLEANING
20 FURNITURE FACTORY
21 AUTO BUSINESS / FURNITURE
22 AUTO BUSINESS
23 FURNITURE FACTORY
24 AUTO BUSINESS
25 FISH CLEANING / WINE SALOON / LEAD LIGHT MANUFATURER / BRICK CLEANING
26 SHOP
27 FURNITURE STORE / DRY CLEANING
28 BAKERY / FLOUR MILL
29 FLOUR MILL
30 FLOUR MILL
31 FLOUR MILL / PLASTIC MOULDING
32 GALVANISING SHOP
33 FURNITURE STORE
34 CAR YARD
35 CAR HIRE AND REPAIR
36 CAR YARD
37 WAREHOUSE
38 AUTO BUSINESS / FACTORY / BRICK CLEANING
39 STAINED GLASS AND LEAD LIGHTS
40 FACTORY / FURNITURE RESTORATION SHOP

REV	DESCRIPTION	DRAWN	CHECK	SUPV	APPR	DATE	DRAWING No	REFERENCE DRAWING
A	ORIGINAL ISSUE	AL	KD	KD	SAB	2/6/99		

	INITIALS	SIGNATURE	DATE
DRAWN	AL		
DRG CHKD	KD		
DESIGNED	KD		
SUPERVISOR			
MANAGER			
APPROVED			

CLIENT: MINISTRY FOR PLANNING

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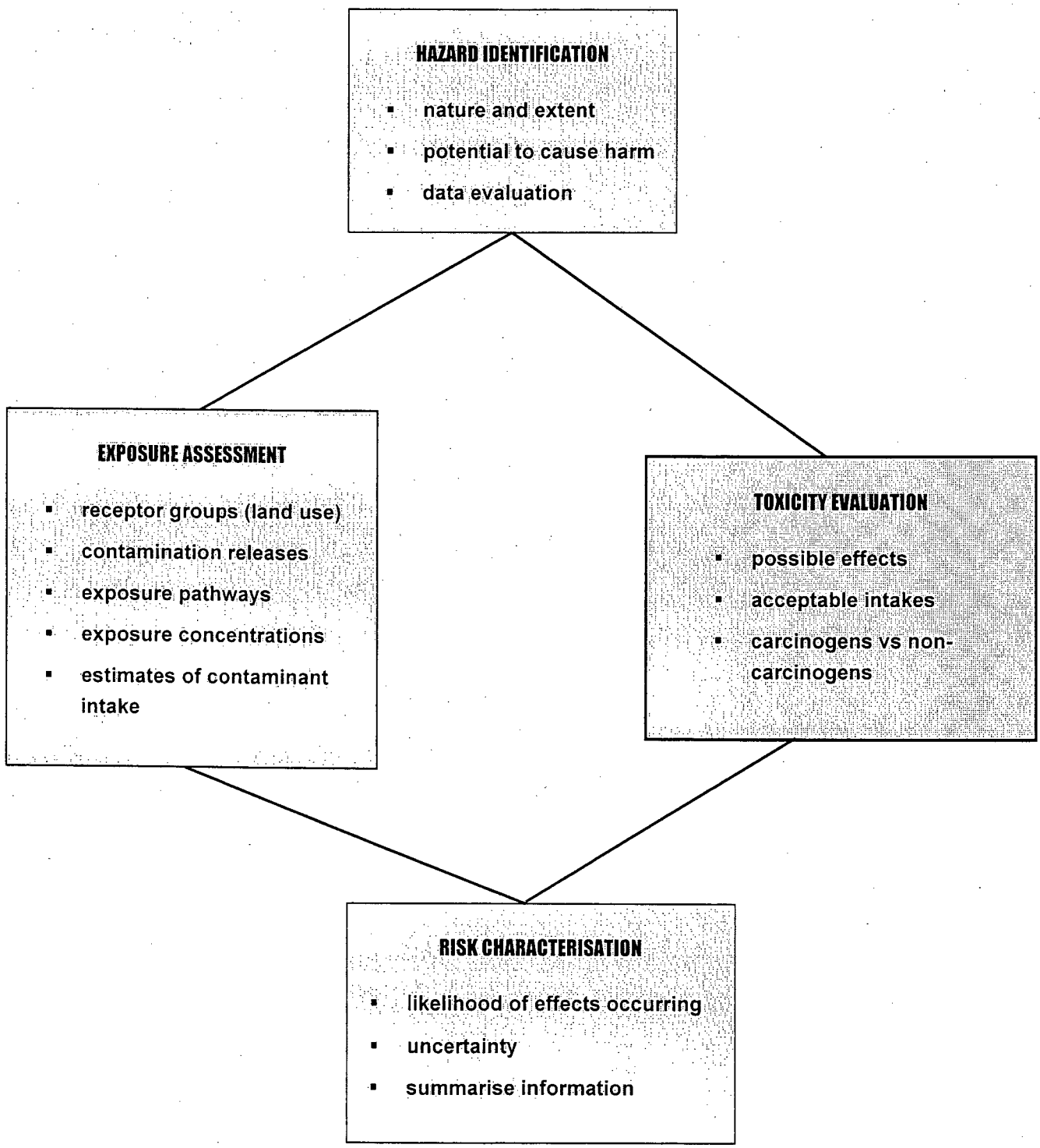
TITLE: NORTHBRIDGE SOIL CONTAMINATION ASSESSMENT CONTAMINATED LAND USE

SIZE	PROJECT No	DRAWING No	SHEET No	REV
A1	VW1216	FIGURE 1	OF	A

CAD FILE No: 1216p400
PLOT INFO XREFS: 11:22 02/06/99

Figure 2 Health Risk Assessment Process



2.2 SITE CHARACTERISATION

This section broadly outlines the nature and extent of the contamination identified in the NRA. It is based on the findings of environmental investigations detailed in the Environmental Review. The physical characteristics and environmental setting of the site are also described.

2.2.1 Hazard Identification

The objective of undertaking this stage of the HRA process is to identify all chemical substances that are present within the NRA which have the potential to cause harm to human health.

Hazardous substances are usually identified by considering which materials may have been used, stored or disposed of on a site, or may have arrived through dumping or site filling. The contaminants identified in the NRA are based on the Phase 1 ESA program which found the following contaminants above environmental investigation levels (these are fully described in Section 2.3):

- Heavy Metals
  - Cadmium
  - Chromium
  - Copper
  - Lead
  - Zinc
- Hydrocarbons (TPH or Total Petroleum Hydrocarbons: aliphatic)
- Chlorinated Hydrocarbons
  - Organochlorine Pesticides (Dieldrin, DDT & derivatives)
  - Polychlorinated Biphenyls (PCB)

It is noted that neither biologically or physically hazardous materials are an issue with the NRA and that only chemical toxicants are considered.

2.2.2 Analytical Results

The analytical results derived from the assessment phase are shown overleaf on Table 1. Only those contaminants which exceeded environmental investigation levels have been included.

TABLE 1
ANALYTICAL RESULTS

All results expressed as milligrams per kilogram

LOCATION	CONTAMINANT	ENVIRONMENTAL INVESTIGATION LEVEL ANZECC B	MAXIMUM CONTAMINANT CONCENTRATION
BLOCK A	NONE	-	-
BLOCK B	Copper	60	240
	Lead	300	3,400
	Zinc	200	950
	Dieldrin	0.2	0.5
	TPH (C_6-C_9)	100	820
BLOCK C	Copper	60	130
	Lead	300	630
	Zinc	200	880
	PCBs	1	4
BLOCK D	Copper	60	220
	Zinc	200	2,100
BLOCK E	Copper	60	410
	Lead	300	780
	Zinc	200	670
BLOCK F	Cadmium	3	3.7
	Chromium	50	100
	Copper	60	150
	Lead	300	3,000
	Zinc	200	1,500
	Dieldrin	0.2	0.5
BLOCK G	NONE	-	-
BLOCK H	Chromium	50	53
	Copper	60	73
	Lead	300	430
	Zinc	200	4,400
	TPH (C_{10}-C_{36})	1000	12,500
BLOCK I	Copper	60	270
	Lead	300	1,000
	Zinc	200	1,000
	Dieldrin	0.2	1.3

2.2.3 Hydrogeology

The Northbridge Redevelopment Area lies primarily within the Spearwood Dune geomorphological unit which is of eolian origin (GSWA, 1986). The lithology of this area is characterised by pale and olive yellow, medium to coarse grained quartz sand derived from Tamala limestone. On the northern flank of the redevelopment in the region of Block F is areas of peaty sand associated with swamp deposits. The lithology is characterised as grey and black quartz sand with peat lenses.

The direction of groundwater flow is generally between south and southeast towards the Swan River. Depth to groundwater ranges from 1m in low lying areas to a maximum of 10 m (WRC, 1997).

2.3 ENVIRONMENTAL INVESTIGATION LEVELS

The Western Australia Department of Environmental Protection (DEP) currently employs the Australian and New Zealand Guidelines for the Assessment of Contaminated Sites (ANZECC/NHMRC 1992) and in their absence for certain chemical compounds, the Dutch Guidelines for Soil Remediation (1983) for the assessment of soil contamination.

The ANZECC guidelines include Environment Investigation Threshold (B) levels and Proposed Health Investigation Level Guidelines. Where contamination is identified at concentrations in excess of the thresholds, further investigation and evaluation on a site-specific basis may be warranted. A site-specific evaluation would include a consideration of future site use, human health risks and other impacts on the nominated beneficial uses.

The ANZECC Health Investigation Level Guidelines apply to lead, cadmium, arsenic and benzo(a)pyrene which are frequently occurring contaminants of significance. These levels have been developed using a health risk assessment approach and can only be applied with reference to particular exposure settings.

Where no Environmental Investigation Threshold is nominated, the ANZECC guideline recommends use of the Dutch B guidelines. It should be noted that the listed concentrations are "investigation thresholds" and indicate the soil contaminant concentration level above which further investigation is required. They are not intended to be regarded as absolute upper bound concentration levels which must not be exceeded.

The Dutch (The Netherlands Department of Housing, Physical Planning and the Environment) guidelines which have been widely used for assessing appropriate levels for a range of contaminants in soils, nominate various action levels for a range of contaminants. The Dutch A levels represent a background or reference value. The Dutch B levels represent an investigation threshold, above which further consideration of the impact of contamination or land use is warranted. Contaminant levels below Dutch B are generally considered acceptable for sensitive landuses such as residential. The Dutch C levels represent a threshold of contamination at which clean-up is likely to be required. Levels below Dutch C are generally considered appropriate for a commercial or industrial land use.

The Risk Assessment and Environmental Quality Division of the Minister of Housing, Spatial Planning and Environment in the Netherlands has provided a revised version of the 1983 Dutch guidelines known as the 1994 Environmental Quality Objectives. The former "A, B and C" criteria have been replaced by target and intervention values. Target levels indicate the concentration of a contaminant in which the risk of adverse effects on the ecosystem and functional properties of the environment are considered to be negligible. The intervention levels are considered contaminant concentrations which represent serious environmental pollution and therefore will require "clean-up" or remediation.

3. EXPOSURE ASSESSMENT

3.1 GENERAL

Exposure assessment involves evaluation of the following key areas:

1. identification of receptor groups, both on-site and off-site;
2. identification of complete exposure pathways;
3. estimation of concentrations in media to which humans may be exposed; and
4. estimation of the exposure likely to be experienced by human receptors.

3.2 RECEPTOR GROUPS

The NRA must be suitable for residential purposes. Therefore the primary receptor group is considered to be future residents living on the redeveloped site which may or may not have been subject to remediation. The most sensitive receptor in this group is considered to be young children of about 2 years of age (toddlers).

The behaviour patterns of toddlers gives rise to the greatest exposure potential to contaminants in soil. They have relatively higher soil ingestion rates, and dermal and inhalational exposures relative to body weight compared to older age groups (NEHF, 1998). Therefore this subgroup of future residents has been identified as the one requiring greatest protection from soil contaminants.

The rate of incidental ingestion of soil by toddlers has been conservatively estimated at 100 mg/day which is approximately four times higher than the adult rate. With their lower body weight and higher daily incidental ingestion of soil, it is considered that young children are at greater risk from soil contaminants than adults. Inhalation and dermal routes of exposure are considered relatively insignificant except for volatile compounds (ANZECC/NHMRC, 1992). Exposure routes are considered in Section 3.3.

By affording protection to this subgroup, all other possible human receptors are therefore covered such as workers involved with soil contact (e.g. gardeners, trench diggers).

3.3 EXPOSURE PATHWAYS

Probable exposure pathways at the NRA are:

- dermal contact with soil;
- ingestion of soil;
- inhalation of soil emissions; and
- consumption of produce grown in contaminated soil.

Consumption of home grown produce is a very unlikely scenario as the proposed residential densities would not provide sufficient space for such gardens. Therefore this exposure pathway is not considered. Groundwater exposure routes have also not been considered in the exposure pathway analysis as this was considered unlikely given the proposed development scenario.

The National Environmental Health Forum (NEHF) 1998 nominates health-based investigation levels (HIL) for soil. These levels are based on health considerations as distinct from environmental protection of soil organisms and plants. Differing HIL's apply to distinct exposure settings. The exposure settings are:

- A 'Standard' residential with garden/accessible soil.
- B Residential with substantial vegetable garden including poultry.
- C Residential with substantial vegetable garden excluding poultry.
- D Residential with minimal opportunities for soil access.
- E Parks, recreational open space and playing fields.
- F Commercial/Industrial.

The greater the opportunity for exposure to soil contaminants, both direct and indirect, the higher the level of protection that is required. Therefore exposure settings D, E and F tolerate a higher level of residual soil contamination compared to residential settings A through to C.

An exceedence of the relevant NEHF value which is the Tier 1 generic health-based criteria normally prompts development of site specific criteria or a Tier 2 risk assessment. The Tier 2 risk assessment considers the level of contamination in context with site specific parameters as distinct from the default parameters used in the NEHF exposure settings.

3.3.1 Exposure Setting for Northbridge Redevelopment

The proposed Northbridge redevelopment will include a mix of high density residential and commercial development. Such developments will provide minimal opportunity for access to soil, so the appropriate Tier 1 assessment of soil contamination is the HIL Exposure Setting D.

Where there is redevelopment with ready access to soil, Exposure Setting D cannot apply so an appropriate exposure setting should be followed with contaminants assessed against the relevant investigation level.

Exposure setting D is described as a *'Residential with minimal opportunities for soil access; includes dwellings with fully and permanently paved yard space such as high-rise apartments and flats'.* Table 2 has been revised to show only those locations which exceed the health based investigation level for Exposure Setting D. These locations are considered to require a site specific health risk assessment which is detailed in Section 5.

The exposure settings used by the NEHF are appropriate to be used for the NRA as they have been determined for Australian conditions and lifestyle choices based on local statistics for population and housing characteristics, residence duration and backyard food production.

Compared to the Exposure Setting - D health investigation level, only two areas; Blocks B and E are considered to require detailed site-specific risk assessment. The contaminants of concern are lead and volatile fraction hydrocarbons. The toxicity of these compounds is discussed in Section 4 with a risk assessment response provided in Section 5.

TABLE 2
ANALYTICAL RESULTS IN EXCESS OF HEALTH INVESTIGATION LEVEL

All results expressed as milligrams per kilogram

LOCATION	CONTAMINANT	HEALTH INVESTIGATION LEVEL	MAXIMUM CONTAMINANT CONCENTRATION
BLOCK A	NONE	-	-
BLOCK B	Lead	1,200	3,400
	TPH (C_6-C_9)	100	820
BLOCK C	NONE	-	-
BLOCK D	NONE	-	-
BLOCK E	NONE	-	-
BLOCK F	Lead	1,200	3,000
BLOCK G	NONE	-	-
BLOCK H	NONE	-	-
BLOCK I	NONE	-	-

4. TOXICITY ASSESSMENT

4.1 GENERAL

Having identified the contaminants and those with the potential for adverse effects, the level of exposure associated with the onset of adverse effects is now evaluated. The level of exposure at which an adverse effect may occur is characterised using a dose-response factor. This information is chemical specific, not site specific.

In considering possible adverse effects on human health, information may be drawn from epidemiological studies (i.e. studies of human populations occupationally or environmentally exposed), animal bioassays (conducted in the laboratory) and a range of cellular tests (e.g. genotoxicity assays).

A toxicity evaluation for each of the hazardous substances of concern present in soils at the NRA is necessary in order to develop acceptable levels protective of human health. Toxicity may be either carcinogenic (i.e. causes cancer) or non-carcinogenic. Discussion and calculation of both types of risk to human health are outlined in Section 5.

4.2 CONTAMINANTS OF CONCERN

The toxicity of those contaminants found at the NRA are subject to a toxicological appraisal to determine whether they are carcinogenic or non-carcinogenic. The identified contaminants above both the relevant human health and environmental investigation levels are outlined in the appraisal.

The health investigation level exposure setting A or "standard residential" has been included to provide an indication of toxicity risk for those compounds with concentrations below the exposure setting D levels.

4.2.1 Heavy Metals

Heavy metal contaminants include cadmium, chromium, copper, lead and zinc, all are considered to be non-carcinogenic with ingestion as the primary exposure pathway. Some metals are more toxic than others with only lead being identified in excess of the high density residential - HIL screening level (exposure setting D).

Cadmium

Cadmium is a relatively toxic metal but was found in the NRA at a maximum concentration of 3.7 mg/kg which is 18% of the Residential Exposure A - HIL. At such low concentrations, cadmium is not considered a health issue.

Chromium

Chromium can result in skin hypersensitivity in sufficient concentration. At the NRA, the maximum observed chromium concentration was 100 mg/kg which is at the Residential Exposure A - HIL. At such low concentrations, chromium is not considered a health issue.

Copper

Copper can be toxic to infants less than one year of age. This receptor group has a minimal exposure to dermal contact or ingestion and are excluded as a receptor group for risk assessment purposes. The maximum observed copper concentration at the NRA is 410 mg/kg which is only 41% of the Residential Exposure A – HIL. At such low concentrations, copper is not considered a health issue.

Lead

High blood lead levels in children has been linked to neurological effects such as decreased IQ. Lead concentrations as high as 3,400 mg/kg have been found at the NRA. This is 11.3 times the Residential Exposure A – HIL. This lead concentration is also 2.8 times the Residential Exposure D – HIL. This lead concentration is considered to require application of site specific risk assessment to fully evaluate potential health risks.

Zinc

Zinc is an essential element required by the body and is not considered as toxic except for intake of significant amounts. The maximum observed zinc concentration at the NRA is 4,400 mg/kg which is 63% of the Residential Exposure A – HIL. At such low concentrations, zinc is not considered a health issue.

4.2.2 Hydrocarbons

Hydrocarbon contaminants include both volatile and heavier fraction petroleum hydrocarbons. There is much complexity regarding this group of chemicals with many that are carcinogenic such as benzene. Where no such carcinogenic or indicator compounds have been detected, the level of risk decreases as a function of limited environmental mobility and low volatility.

Volatile Fractions

The NEHF has not set HIL's for volatile hydrocarbon fractions ($<C_{15}$) due to complex environmental behaviour pathways and carcinogenicity issues. The exposure pathway related to soil emissions is an important consideration, especially in permeable soils such as sands with a high potential for vapour transfer. The observed volatile hydrocarbon concentrations were 820 mg/kg or 8.2 times the Dutch B criteria. As there are no HIL's for this fraction, application of a site specific risk assessment is required to fully evaluate potential health risks.

Heavy Fraction

Heavy fraction hydrocarbon contamination was detected at 2.2 times the Residential Exposure A – HIL. However the TPH concentration is only 55% of the Residential Exposure D – HIL. Given that the level is below the high density residential criteria, no further risk assessment is required for that particular landuse.

4.2.3 Chlorinated Hydrocarbons

Chlorinated hydrocarbons are a very stable group of chemicals which are persistent in the environment. This group includes organochlorine (OC) pesticides and PCB's. OC pesticides have been implicated as possible Group 2B carcinogens (IRIS, 1999). Such carcinogens are considered probable with evidence of cancers in animals but not humans.

The primary exposure pathways with this group is dermal and inhalation uptake.

OC Pesticides

The maximum observed OC concentration was 1.3 mg/kg which is 13% of the Residential Exposure A – HIL. At such low concentrations, OC's are not considered a health issue.

PCB's

PCB's were detected in only one location throughout the whole NRA at a concentration of 4 mg/kg. This level is 40% of the Residential Exposure A – HIL. At such low concentrations, PCB's are not considered a health issue.

5. RISK CHARACTERISATION

5.1 GENERAL

The results of the exposure and toxicity assessments are combined to provide an estimate of the risk of adverse effects to human health. As part of the risk characterisation component, consideration should be given to both:

- presenting the uncertainty associated with the risk estimates, and
- communication of risk estimates to relevant decision makers.

The risk to future residents at the NRA based on the findings of the Phase 1 ESA and toxicity assessment performed as part of this HRA, is from exposure to lead and volatile hydrocarbon contaminated soil. To assess the risk posed by these contaminants a site specific risk assessment is required which incorporates site conditions rather than generic assumptions regarding exposure pathways.

The calculation of risk for both carcinogenic and non-carcinogenic substances is described in the following sections.

5.1.1. Calculation of Non-carcinogenic Risk

Non-carcinogenic risk is evaluated by comparing the exposure level of a substance over the duration of exposure against a reference dose (RfD) derived for a similar exposure period. The reference dose or Tolerable Daily Intake (TDI) is a safe intake of a substance over a particular exposure period with no adverse health effects. There are both chronic and sub-chronic RfD's for assessing short or long term exposures.

The TDI has been determined by the National Health and Medical Research Council or the World Health Organisation and is the toxicological basis for levels derived in the 1998 NEHF health investigation levels.

The ratio of exposure for a particular chemical and the individual pathway to the RfD is called the hazard quotient (HQ). The HQ's are usually added together across all chemicals and exposure routes to estimate the hazard index (HI). If the HI is below 1, no adverse health effects occur, even if the receptor is exposed to this dose continuously over a lifetime. Hazard indices above 1 indicate a potential health risk and the need for further investigation work or remedial action.

5.1.2. Calculation of Carcinogenic Risk

Carcinogenic risk assumes that exposure to any amount of a carcinogen will increase the risk of cancer and that there is no safe (zero risk) dosage. Carcinogenic risk is based on incremental probability, so the greater the exposure, the higher the risk. This potency factor is referred to as the slope factor.

The slope factor is the result of application of a low-dose extrapolation procedure and is applied to the LADD (lifetime average daily dose) to determine the individual excess lifetime cancer risk or IELCR. The IELCR or carcinogenic risk is expressed as the chance of developing cancer, normally expressed at 1 in 10,000, 1 in 100,000 or 1 in 1,000,000.

5.2 LEAD

Lead is a difficult chemical to assess as there is no validated toxicity criteria and developing a site specific Tier 2 response level is beyond the scope of most risk assessment projects and generic computer models. For all compounds except lead an acceptable daily exposure can be derived. Whereas for lead, acceptability is based on blood lead levels which can only be calculated using a physiologically-based pharmacokinetics model.

The NEHF recommends that the conservative HIL's should be used rather than the results of biokinetic modelling which generate higher values for tolerable lead levels in soil. Given the complexity in determining site specific lead levels and the conservatism surrounding lead and its effects on young children, the proposed response level for the NRA is the HIL Residential Exposure Setting D value of 1,200 mg/kg.

5.3 VOLATILE HYDROCARBONS

Volatile hydrocarbons present a risk to human health as outlined previously in Section 4. The contamination detected was subject to a site specific health risk assessment using the BP RISC (Risk-Integrated Software for Cleanups) software program. The results of the risk modelling are attached as Appendix A. An outline of the software model, assumptions and parameters used in its application are described in Section 5.4.

The risk assessment considered the following exposure pathways:

- Ingestion of soil,
- Dermal contact with soil, and
- Inhalation of outdoor air.

The hazard index (HI) for each route of exposure is shown as Figure 3 and is discussed in the following sections. The total HI for all exposure routes is around 7E-05 or $7X10^{-5}$ which is at least four orders of magnitude below the hazard risk of 1. Therefore the presence of the volatile soil contamination does not represent a risk to human health and does not require remedial action.

No groundwater exposure pathways were considered as part of the site specific risk assessment as access to groundwater was unlikely.

The modelling exercise was undertaken on a receptor who is both a child and adult occupying the site with access to the soil. This is a conservative scenario, as a child has much more exposure to soil, combined with a lower body weight resulting in a higher contaminant burden compared to an adult.

5.3.1 Ingestion of Soil

Ingestion of soil is calculated to be the most significant exposure route for a child with a very low hazard index of 3.29E-04 which is four orders of magnitude below the hazard risk of 1. Ingestion as a child represents the greatest possible health risk from the hydrocarbon contamination.

5.3.2 Dermal Contact

Dermal contact is calculated to be the main exposure route for an adult with a very low hazard index of 5.20E-05. The child hazard index was 3.23E-04.

5.3.3 Inhalation of Outdoor Air

Inhalation is a minor exposure route with respective child and adult hazard indices of 3.79E-05 and 8.33E-06. The calculated current average outdoor air concentration based on the vadose soil model is 0.215 mg/m^3.

5.3.4 Degradation Rate

The soil vapour emissions and soil concentrations (vadose soil model) are expected to decline rapidly within two years to effectively a zero level. This is however a simple computer model prediction which is based on a number of assumptions and should be viewed only as a guide.

Given that the volatile hydrocarbons are rapidly degrading due to volatilisation, the contamination will be considered remediated in approximately two years and will no longer be an environmental or human health issue. Should buildings or hardstand surfaces be constructed over the contamination, the rate of degradation is expected to significantly reduce compared to an open outdoor scenario.

5.4 RISK ASSESSMENT MODEL

The BR RISC (Risk-Integrated Software for Cleanups) software program can be used to estimate the potential for adverse human health impacts for up to nine exposure pathways. The software also contains vadose zone, saturated zone, and air and fate transport models for estimating receptor point concentrations.

With regard to the NRA, BP RISC has been used to determine the hazard index (HI) for Aliphatic TPH (C_6-C_8). The inhalation exposure pathway was calculated using a Vadose Soil Model which simulates contaminant transport through unsaturated soil. This fate and transport model is one dimensional using an advective-dispersion solute transport equation. Volatilisation losses are used as the source in a box model which is used to calculate outdoor air concentrations. Algorithms then determine the HI for each of the nominated exposure pathways.

Limitations of the BP RISC model are:

- water table fluctuations are not considered,
- contaminant source has a uniform concentration across the specified volume, and
- derived moisture content is constant for the entire depth of the soil column.

6. UNCERTAINITY ANALYSIS

This health risk assessment has been performed using analytical information supplied in the Environmental Review for the Northbridge redevelopment. Given that the Phase 1 environmental site assessment comprised 307 sampling locations over an area of 11.8 ha which did not include non-government land, there exists the potential that "hot spots" of significant contamination may have been missed. Adoption of maximum contaminant concentrations for assessment purposes should reduce the chance of underestimating potential exposure levels.

Levels adopted in this risk assessment for all contaminants other than volatile hydrocarbons is based on a high density residential exposure setting where there is no ready access to soil. Should areas of the redevelopment have access to soil such as parks, the allowable level of contaminants in the soil will reduce. This variation in allowable soil levels applies only to lead and heavy fraction hydrocarbons. For all other tested contaminants, adoption of more sensitive exposure settings is not an issue.

The response levels for lead and heavy fraction hydrocarbons is taken from the NEHF health investigation levels which are shown on Table 3. A commercial setting (NEHF Exposure Setting F) has also been included for reference purposes.

TABLE 3
PROPOSED RESPONSE LEVELS
All results expressed as milligrams per kilogram

CONTAMINANT	RESIDENTIAL EXPOSURE SETTING A	HIGH DENSITY RESIDENTIAL EXPOSURE SETTING D	PARKS/OPEN SPACE EXPOSURE SETTING E	COMMERCIAL EXPOSURE SETTING F
Lead	300	1,200	600	1,500
Heavy Fraction Aliphatic TPH	5,600	22,400	11,200	28,000

7. REFERENCES

ANZECC/NHMRC 1992 — *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.* Australian and New Zealand Environment and Conservation Council/National Health and Medical Research Council.

Dutch 1983 — *Guidelines for Soil Remediation.* The Netherlands Department of Housing, Physical Planning and the Environment.

Dutch 1994 — *Environmental Quality Guidelines in the Netherlands.* Ministry of Housing, Spatial Planning and the Environment.

GSWA 1986 — *Environmental Geology Series Map (1:50,000), Perth Sheet.* Geological Survey of Western Australia.

NEHF 1998 — *Health – Based Soil Investigation Levels.* National Environmental Health Forum Monographs. Soil Series No. 1. Second Edition, South Australian Health Commission.

NEPC 1998 — *Discussion Paper: Towards a National Environment Protection Measure for the Assessment of Contaminated Sites.* National Environment Protection Council Committee.

US EPA 1999 — *Integrated Risk Information System (IRIS).*

WRC 1997 — *Perth Groundwater Atlas.* Water and Rivers Commission.

APPENDIX A

CALCULATION OF RISK-FOR ALIPHATIC TPH (C_6-C_8)

Title:
New Project

File not saved

Scenarios:
Adult Resident - Typical

Child Resident - Typical

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL
INHALATION OF OUTDOOR AIR

Chemicals:
TPH Aliphatic C6-8

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2
Lifetime and Body Weight		
Body Weight (kg)	70.00	16.00
Lifetime (years)	70.00	70.00
INGESTION OF SOIL		
Soil Ingestion Rate (mg/day)	40.00	90.00
Exp. Frequency Soil (events/year)	40.00	130.00
Exp. Duration Soil (years)	9.00	5.00
Absorption Adjustment Factor for Ingestion of Soil (-)		
TPH Aliphatic C6-8	1.0	1.0
Soil Bioavailability (-)		
TPH Aliphatic C6-8	1.0	1.0
DERMAL CONTACT WITH SOIL		
Fraction Skin Exposed to Soil (-)	.11	.13
Adherence Factor for Soil (mg/cm^2)	.20	.20
Exposure Freq. Soil (events/year)	40.00	130.00
Exposure Duration Soil (years)	9.00	5.00
Absorption Adjustment Factor for Dermal Exposure to Soil (-)		
TPH Aliphatic C6-8	.50	.50
Soil Bioavailability (-)		
TPH Aliphatic C6-8	1.0	1.0
INHALATION OF OUTDOOR AIR		
Inhalation rate (m^3/hr)	.83	.83
Time outdoors (hours/day)	1.10	2.20
Lung Retention Factor (-)	1.00	1.00
Exp. Freq. Outdoor Air (events/yr)	350.00	130.00
Exp. Duration Outdoor Air (yr)	9.00	5.00
Absorption Adjustment Factor for Inhalation (-)		
TPH Aliphatic C6-8	1.0	1.0

MEDIA CONCENTRATIONS

Concentration in Outdoor Air (mg/m^3)
Obtained from Fate and Transport output
AVERAGE Concentration (over exposure duration)
(used to calculate carcinogenic risk)

Exposure Duration (years)	9.0	5.0
TPH Aliphatic C6-8	2.61E-03	4.70E-03

Concentration used to calculate hazard index
(Minimum of 7 years or exposure duration)

Exposure Duration (years)	7.0	5.0
TPH Aliphatic C6-8	3.36E-03	4.70E-03

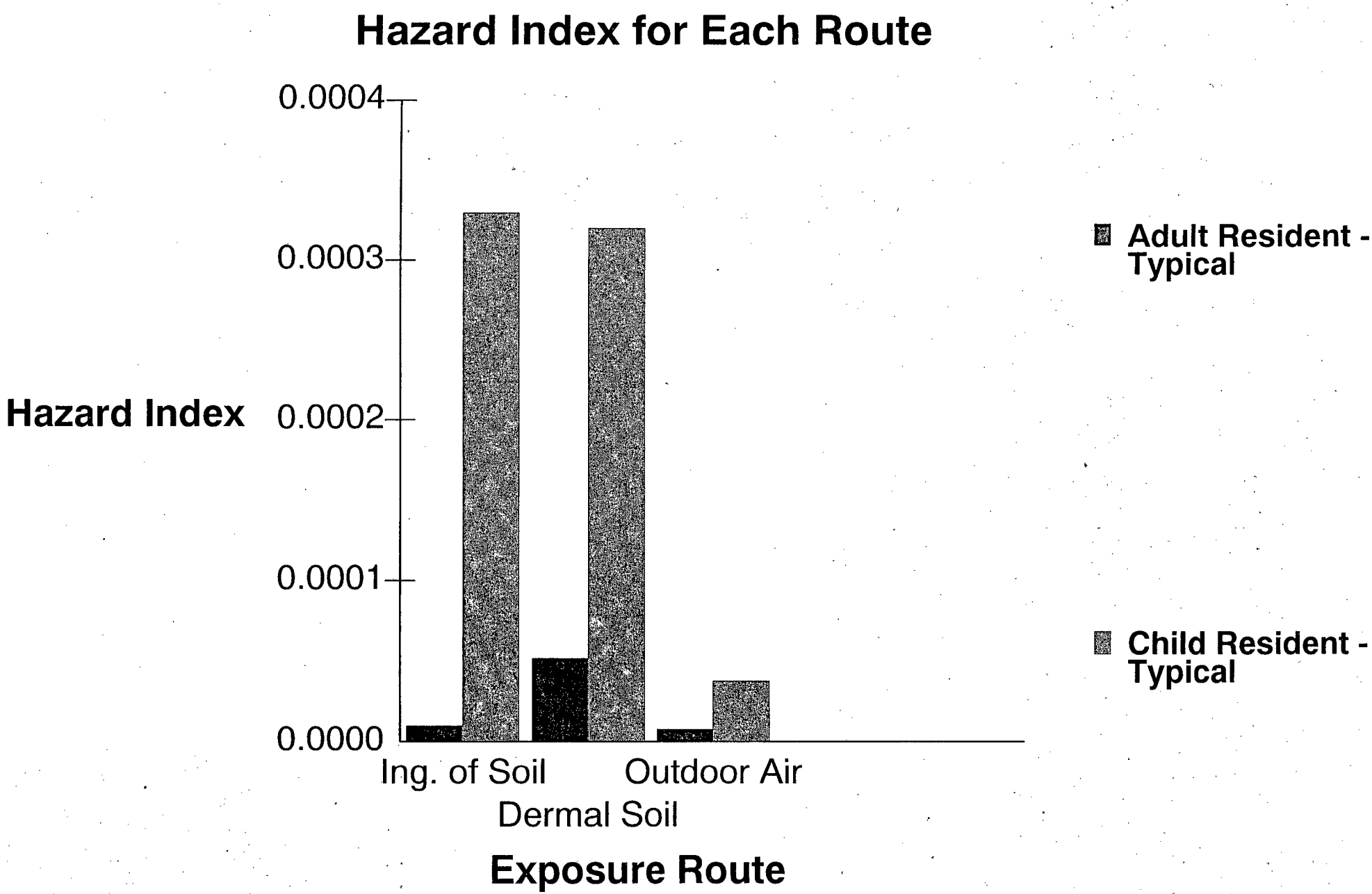
Concentration in Soil (mg/kg)
Used in calculating carcinogenic risk and hazard index

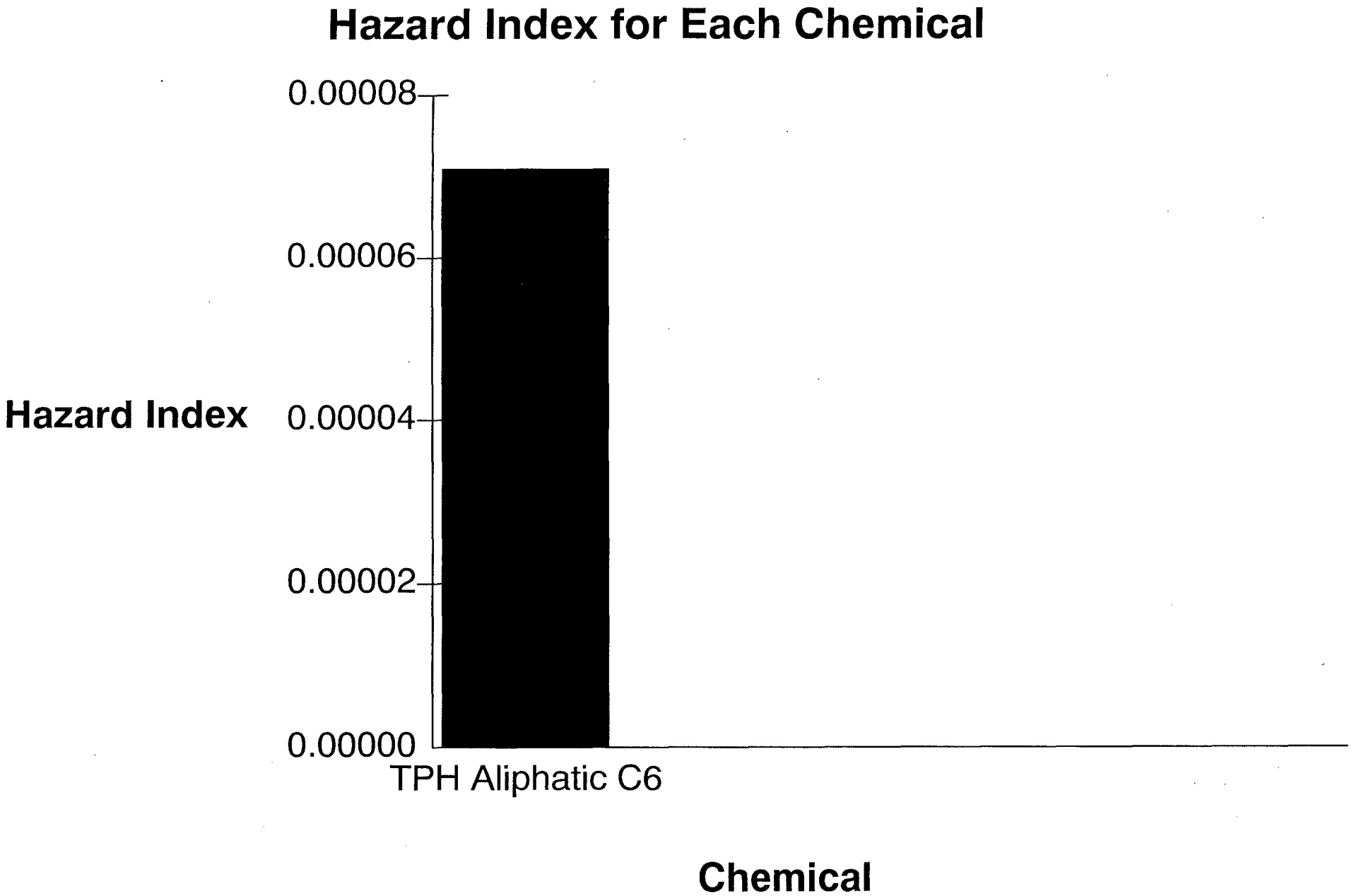
TPH Aliphatic C6-8	8.20E+02	8.20E+02

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]		
TPH Aliphatic C6-8	ND	ND
Ingestion Reference Dose (mg/kg-day)		
TPH Aliphatic C6-8	5.0	5.0
Inhalation Slope Factor [1/(mg/kg-day)]		
TPH Aliphatic C6-8	ND	ND
Inhalation Reference Dose (mg/kg-day)		
TPH Aliphatic C6-8	5.0	5.0
Dermal Slope Factor [1/(mg/kg-day)]		
TPH Aliphatic C6-8	ND	ND
Dermal Reference Dose (mg/kg-day)		
TPH Aliphatic C6-8	5.0	5.0

SUMMARY OF RESULTS	SCENARIO: 1	2
INGESTION OF SOIL		
TPH Aliphatic C6-8		
CDI (mg/kg-day)	5.14E-05	1.64E-03
LADD (mg/kg-day)	6.60E-06	1.17E-04
Cancer Risk (-)	0.00E+00	0.00E+00
Hazard Index (-)	1.03E-05	3.29E-04
DERMAL CONTACT WITH SOIL		
TPH Aliphatic C6-8		
CDI (mg/kg-day)	2.60E-04	1.61E-03
LADD (mg/kg-day)	3.34E-05	1.15E-04
Cancer Risk (-)	0.00E+00	0.00E+00
Hazard Index (-)	5.20E-05	3.23E-04
INHALATION OF OUTDOOR AIR		
TPH Aliphatic C6-8		
CDI (mg/kg-day)	4.20E-05	1.91E-04
LADD (mg/kg-day)	4.20E-06	1.37E-05
Cancer Risk (-)	0.00E+00	0.00E+00
Hazard Index (-)	8.33E-06	3.79E-05


Hazard Index for Each Route
Hazard Index
0.0004
0.0003
0.0002
0.0001
0.0000
Ing. of Soil
Outdoor Air
Dermal Soil
Exposure Route
Adult Resident - Typical
Child Resident - Typical


Hazard Index for Each Chemical
Hazard Index
0.00008
0.00006
0.00004
0.00002
0.00000
TPH Aliphatic C6
Chemical

Vadose zone model used to estimate outdoor air concentration

Title: New Project

Simulation time (years)..... 10

Vadose Zone Source Parameters

Thickness of contamination (m).....	.500
Depth to top of contamination (m).....	.000
Length of source (m).....	10.0
Width of source (m).....	10.0

Unsaturated Zone Properties

Total Porosity in vadose zone (cm3/cm3)	.300
Residual water content (cm3/cm3).....	5.000E-02
Fraction organic carbon (g oc/g soil)...	2.000E-03
Soil bulk density (g/cm3).....	1.70
Infiltration Rate (cm/yr).....	85.0
Saturated conductivity (m/d).....	5.00
Van Genuchten"s N.....	2.68
Thickness of vadose zone (m).....	4.00
Air content in capillary fringe(cm3/cm3)	.000

OUTDOOR AIR PARAMETERS

Height of box (breathing zone) (m).....	2.00
Width of box (m).....	10.0
Wind speed (m/s).....	4.70

TPH Data for Unsaturated Zone Source

Concentration of TPH in soil (mg/kg)....	.000
Molecular weight of TPH (g/mol).....	.000

CHEMICAL DATA INPUT: TPH Aliphatic C6-8

Diffusion coeff. in air (cm2/s).....	.100
Diffusion coeff. in water (cm2/s)...	1.000E-05
Solubility (mg/l).....	5.40
KOC (ml/g).....	3.980E+03
Henry"s Law Coefficient (-).....	51.0
Molecular Weight (g/mol).....	100.
Density of chemical (g/cm3).....	.680
Degradation rate sat. zone (1/d)....	.000
Degradation rate unsat. zone (1/d)..	.000

Source Concentrations: TPH Aliphatic C6-8

Source Conc. for unsaturated zone model (mg/kg)... 820.

MODEL OUTPUT FOR: TPH Aliphatic C6-8

VADOSE ZONE MODEL OUTPUT

Effective Diffusion Coefficient for Vadose zone

Total thickness of subunit [cm]	1.00E+00
Air-filled porosity [-]	2.00E-01
Water-filled porosity [-]	1.00E-01
Total porosity [-] (sum of air-filled and water-filled porosities)	3.00E-01
Effective diff. coeff. for subunit....[cm^2/s]	5.18E-03

Effective Diffusion Coefficient for Lens

Total thickness of subunit [cm]	0.00E+00
Air-filled porosity [-]	9.16E-02
Water-filled porosity [-]	1.58E-01
Total porosity [-] (sum of air-filled and water-filled porosities)	2.50E-01
Effective diff. coeff. for subunit....[cm^2/s]	5.55E-04

Source concentration is ABOVE residual limit

Source total decay term--Beta	6.803E-02
Source loss term--liquids only [1/day]	1.804E-05
Source loss term--vapor only [1/day]	6.801E-02
Initial source vapor concentration [kg/m^3]	2.754E-01
Diffusion path length [m]	2.600E-01
Average vertical thickness of the source[m]	5.000E-01

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Dispersivity limited to dispmax: .146E-04

Calculated vertical dispersion coefficient (m^2/day) 1.46E-05

CUMULATIVE LOSSES (from the Unsaturated Zone)
TPH Aliphatic C6-8

Time (yr)	Total Mass in Source (kg)	Mass Loading to Groundwater (kg)	Volatilization Losses (kg)	Liq. Mass Los From Source (kg)

1.0	1.15E-09	0.00E+00	6.97E+01	1.85E-02
2.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
3.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
4.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
5.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
6.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
7.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
8.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
9.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02
10.0	1.51E-15	0.00E+00	6.97E+01	1.85E-02

VADOSE ZONE CONCENTRATION WITH DEPTH
TPH Aliphatic C6-8

TIME .0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	5.40E+00	7.57E+01
.9	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.7	0.00E+00	0.00E+00
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00
3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

TIME 1.0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	8.88E-11	1.24E-09
.9	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.7	0.00E+00	0.00E+00
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00
3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

TIME 2.0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	1.46E-21	2.05E-20
.9	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.7	0.00E+00	0.00E+00
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00

3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

TIME 3.0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	2.40E-32	3.36E-31
.9	0.00E+00	0.00E+00
1.3	0.00E+00	0.00E+00
1.7	0.00E+00	0.00E+00
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00
3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

TIME 4.0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	3.95E-43	5.53E-42
.9	1.56E-44	2.18E-43
1.3	0.00E+00	0.00E+00
1.7	0.00E+00	0.00E+00
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00
3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

TIME 5.0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	6.49E-54	9.09E-53
.9	6.65E-12	9.32E-11
1.3	3.64-122	5.11-121
1.7	0.00E+00	0.00E+00
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00
2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00
3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

TIME 10.0 years

Depth (m)	Liquid Phase Concentration (mg/l)	Total Soil Concentration Below Source (mg/kg)
.5	7.80-108	1.09-106
.9	2.92E-34	4.09E-33
1.3	0.00E+00	0.00E+00
1.7	1.53E-83	2.15E-82
2.1	0.00E+00	0.00E+00
2.5	0.00E+00	0.00E+00

2.8	0.00E+00	0.00E+00
3.2	0.00E+00	0.00E+00
3.6	0.00E+00	0.00E+00
4.0	0.00E+00	0.00E+00

LIQUID PHASE CONCENTRATION
TPH Aliphatic C6-8

Time (yr)	Concentration at source (mg/l)	Concentration at Water Table (mg/l)
.0	5.40E+00	0.00E+00
1.0	4.92E-02	0.00E+00
2.0	8.09E-13	0.00E+00
3.0	1.33E-23	0.00E+00
4.0	2.19E-34	0.00E+00
5.0	3.60E-45	0.00E+00
6.0	5.91E-56	0.00E+00
7.0	9.72E-67	0.00E+00
8.0	1.60E-77	0.00E+00
9.0	2.63E-88	0.00E+00
10.0	4.32E-99	0.00E+00

OUTDOOR AIR CONCENTRATION
TPH Aliphatic C6-8

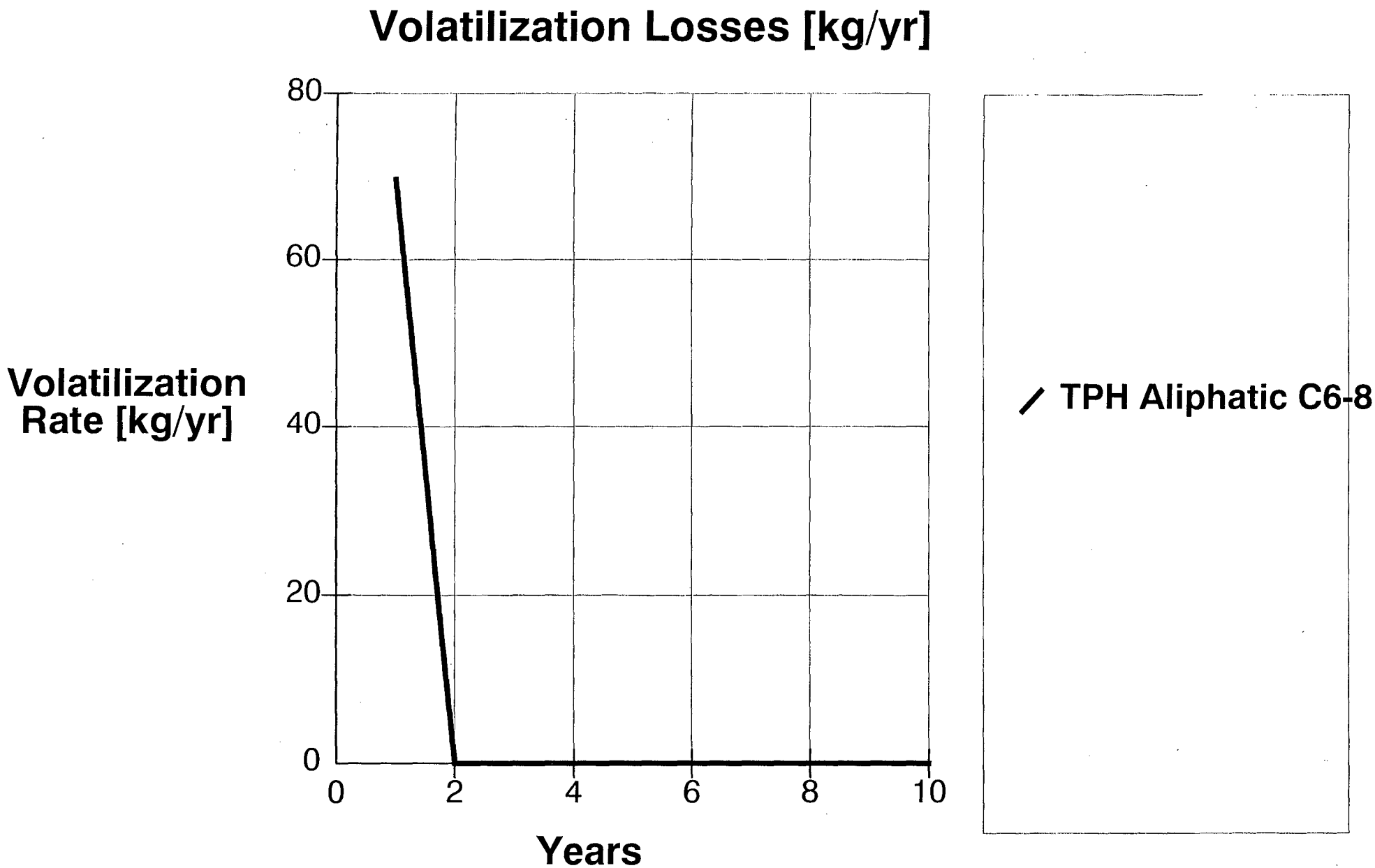
Time (yr)	Concentration Outdoors (mg/m^3)
1.0	2.35E-02
2.0	3.87E-13
3.0	0.00E+00
4.0	0.00E+00
5.0	0.00E+00
6.0	0.00E+00
7.0	0.00E+00
8.0	0.00E+00
9.0	0.00E+00
10.0	0.00E+00

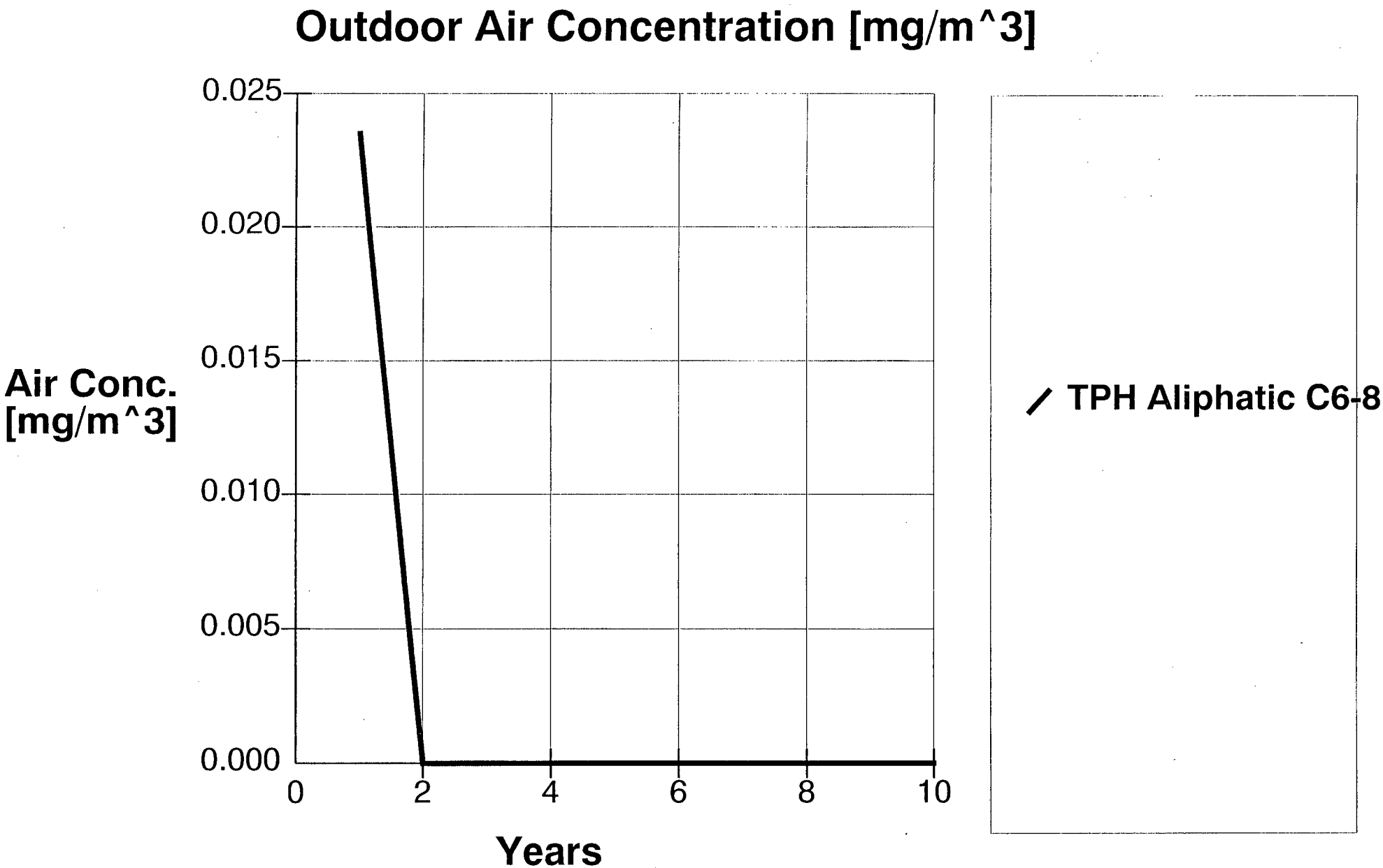
The maximum concentration occurred at the following time:

.1	2.15E-01

SOIL CONCENTRATION AT SOURCE AND WATER TABLE
TPH Aliphatic C6-8

Time (yr)	Concentration in Source (mg/kg)	Concentration at Water Table (mg/kg)
.0	8.20E+02	0.00E+00
1.0	7.47E+00	0.00E+00
2.0	1.23E-10	0.00E+00
3.0	1.78E-14	0.00E+00
4.0	1.78E-14	0.00E+00
5.0	1.78E-14	0.00E+00
6.0	1.78E-14	0.00E+00
7.0	1.78E-14	0.00E+00
8.0	1.78E-14	0.00E+00
9.0	1.78E-14	0.00E+00
10.0	1.78E-14	0.00E+00


Volatilization Losses [kg/yr]
Volatilization Rate [kg/yr]
80
60
40
20
0
0
2
4
6
8
10
Years
TPH Aliphatic C6-8


Outdoor Air Concentration [mg/m^3]
Air Conc. [mg/m^3]
0.025
0.020
0.015
0.010
0.005
0.000
0
2
4
6
8
10
Years
TPH Aliphatic C6-8

Soil Concentration in the Vadose Source [mg/kg]