Prepared for:

Victorian Rail Track Access

GPO Box 1681
Melbourne VIC 3000





Environmental Audit Report

Southern Portion of Lot 38, Frankston-Flinders Road, Somerville Victoria

ENSR Australia Pty Ltd (HLA ENSR)

12 December 2007

Document No.: M4054801_R001_12Dec07 - Converted.doc

Merged with ENSR in 2007

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Southern Portion of Lot 38, Frankston-Flinders Road
Somerville, Victoria

12 December 2007

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Michael Seignior
Environmental Auditor
Appointed Pursuant to the *Environment Protection Act* 1970

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1.0 Introduction

This Environmental Audit report and Certificate of Environmental Audit (see **Appendix B**) was prepared in response to a request by Stephen Hamilton on behalf of Victorian Rail Track Access (VicTrack). VicTrack requested that a Certificate of Environmental Audit be issued, in accordance with EPA Victoria regulations and guidelines, for the property located at the southern portion of Lot 38, Frankston-Flinders Road, Somerville, Victoria (the Site). Refer to **Figure 1** for the site locality.

Mr Michael Seignior, an employee of ENSR Australia Pty Limited (HLA ENSR) and an Environmental Auditor appointed pursuant to the *Environment Protection Act* 1970, performed this audit in accordance with the *Environmental Auditor (Contaminated Land) Guidelines for Issue of Certificates and Statements of Environmental Audit* (EPA Publication 759.1).

Information relating to the Site and the environmental audit process is summarised as follows:

Environmental Auditor	Michael Seignior
Date of appointment as an auditor under the Act	4 March 2003 Subsequently reappointed on 4 March 2004, 5 March 2005, and 3 March 2007.
Person making request for a Certificate	Stephen Hamilton
Where the person is making the request is not the owner or occupier of the Site or EPA, authorisation by the occupier for the person to request the Certificate	Mr Stephen Hamilton is an employee of VicTrack
Date of request	21 September 2006
Site Description / Location	Southern portion of Lot 38, Somerville, Victoria (See survey results in Appendix C.)
AMG Coordinates	Approx. 340502E, 5767432N
Municipality	Mornington Peninsula Shire
Parish	Tyabb
Current Zoning	Public Use (Transport) Zone (PUZ4), Crown Land
Title References	Vol 09974 Fol 846
Planning Application No.	N/A
Area	8000m2
Completion date	12 December 2007
Assessment Consultant	Atma Environmental Pty Ltd

Refer to Appendix C for a copy of the survey plan of the southern portion of Lot 38 of the Site.

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2.0 Information Sources

2.1 Assessment Consultants

The appointed assessment consultant, Atma Environmental Pty Ltd (Atma), supplied the primary sources of information that the Auditor used to form an opinion regarding the environmental condition of the Site and to complete this environmental audit. This information comprised the following:

- The following written reports produced by the assessment consultant:
  - Preliminary Environmental Site Assessment: Lot 38, Somerville, Victoria, December 2006 (referred to herein as the Atma PESA).
  - Environmental Site Assessment: Lot 38, Somerville, Victoria, April 2007 (referred to herein as the Atma ESA).
- Various discussions between the Auditor, Atma and VicTrack.
- Various documents and plans issued by Atma and VicTrack.
- Copies of work plans, preliminary results, preliminary assessment reports, etc. from Atma. The Auditor provided regular written feedback to the assessment consultant regarding the adequacy of this information for the purposes of completing an environmental audit.

2.2 Site Inspections

A site inspection was conducted by the Auditor on 28 September 2006. In addition, a site inspection during fieldworks was conducted by the auditor's assistant on 24 January 2007.

The purpose of the site inspection was to become familiar with the physical nature of the Site and surrounding area and to visually assess the environmental condition of the Site and to review field investigation techniques used by the assessment consultant and to collect soil and groundwater quality control (QC) samples.

2.3 Expert Support Team

The Auditor drew upon the assistance of Dr. Robert van de Graaff of the Auditor's approved expert support team, specialising in soil science.

In conducting this audit, support has been provided by Ms Melinda Thompson (Senior Environmental Engineer) and Mr Ho Nguyen (Project Environmental Engineer) at HLA ENSR's Melbourne office.

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3.0 Audit Data Quality Objectives

As defined in the *Environment Protection Act* 1970, an environmental audit is:

> "*a total assessment of the nature and extent of any harm or detriment caused to, or the risk of any possible harm or detriment which may be caused to, any beneficial use made of any segment of the environment by any industrial process of activity, waste, substance (including any chemical substance) or noise*".

An environmental audit (contaminated land) taken to completion results in the issue of a Certificate of Environmental Audit ('Certificate'). If the Auditor determines not to issue a Certificate, he/she must issue a Statement of Environmental Audit ('Statement').

A Certificate indicates that the Auditor is of the opinion that the Site is suitable for any beneficial use; that there is no restriction on use of the Site due to its environmental condition. A Statement indicates that the Auditor is of the opinion that there is, or may be, some restriction on the use of the Site.

When undertaking an environmental audit, the Auditor must first satisfy him/herself as to whether the environmental condition of the land is suitable to issue a Certificate. This involves the following:

- an evaluation of the environmental quality of the Site;
- an assessment of whether any clean up is required to the Site; and
- if any clean up is required, providing recommendations relating to the clean up of the Site.

Such work usually involves consideration of historical practices of the Site and surrounds which may have given rise to site contamination and a site investigation to assess the environmental condition of soil and/or groundwater. The significance of the results of the investigation work is used to determine the need for clean up works and if a Certificate can be issued.

3.1 Guidance Documents

In completing this environmental audit, the Auditor has drawn upon a range of data in forming an opinion regarding the environmental condition of the Site. The amount, quality and nature of the data required to form this opinion is consistent with that recommended in relevant guidelines and standards. In particular, a key guidance document for environmental auditing of contaminated land is:

- EPA Publication 759.1, Environmental Auditor (Contaminated Land) Guidelines for Issue of Certificates and Statements of Environmental Audit (September 2007)

Other key guidance documents are:

- National Environment Protection (Assessment of Site Contamination) Measure, National Environment Protection Council, 1999
- AS 4482.1-2005,Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 1: Non-volatile and Semi-volatile Compounds
- AS 4482.2-1999, Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 2: Volatile Substances
- EPA Publication 441.7, A Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Wastes, March 2000

- EPA Publication 668 – *Hydrogeological Assessment (Groundwater Quality) Guidelines*. (EPA Victoria, 2006)
- EPA Publication 669 – *Groundwater Sampling Guidelines*. (EPA Victoria, 2000)

Specific data quality objectives used for this audit, together with a discussion regarding the degree of compliance in relation to specific elements of this environmental audit, are provided in **Section** Error! Reference source not found. of this audit report.

3.2 Legislation

When conducting an environmental audit (contaminated land) the following are key pieces of legislation that need to be considered:

- Environment Protection Act 1970
- State environment protection policy (Prevention and Management of Contamination of Land)
- State environment protection policy (Groundwaters of Victoria)
- State environment protection policy (Waters of Victoria)
- State environment protection policy (Air Quality Management)
- Industrial Waste Management Policy (Prescribed Industrial Waste)
- Industrial Waste Management Policy (Waste Acid Sulfate Soils)

4.0 Site History and Setting

4.1 Site History

A review of historical developments and activities that have taken place on the Site is documented in the Atma PESA (**Attachment 1**). Site history information reviewed included the following:

- Historical information from VicTrack;
- Hydrogeological information;
- EPA Victoria's Priority Sites Register;
- Historical Aerial Photographs; and
- Historical Certificates of Title.

Based on this historical information, the past uses of the Site are understood to be:

- Vacant land, sometimes used as a carpark and possible rail use;
- Possible orchard;
- Possible vineyard; and
- Possible sheep grazing.

4.2 History of Surrounding Land Use

The surrounding land has historically been used for a mixture of agricultural and residential uses. All properties immediately surrounding the Site to the north, east across Frankston-Flinders Road, and west across the railway are established long term residential allotments. A children's learning centre is located immediately to the southeast. Vacant land is located directly northeast of the Site with the Somerville Railway Station 200m to the northeast of the Site. The land to the northwest of the Site is used for industrial purposes.

4.3 Current Site Use

The Site is currently a vacant block of land and was most recently used as a car park. The Site is a rectangular block covered mainly by grass with a few trees and there are no buildings. Green waste was present as stockpiles on the southern boundary of the Site. In addition, there is a low-lying area containing ballast on the western portion of the Site. The Site layout is shown in Figure 2 of the Atma PESA (**Attachment 1**).

4.4 Proposed Development

There are currently no plans to develop the Site. However, it is understood that VicTrack wish to divest the Site.

4.5 Topography

The Site is generally flat with surface drainage directed to the northeast. Regionally there is a gentle slope to the northeast to Watson Creek approximately 2km from the Site.

4.6 Geology

The Queenscliff 1:250,000 Geological Map of Victoria shows the Site to be underlain by the Baxter Sandstone sediments which consists of ferruginous sandstone, sandy clay to clay.

The generalised soil profile detailed in **Section 3.5** of the Atma PESA (**Attachment 1**) can be summarised as follows:

Approximate Depth (from/to) (m bgs)	Lithological Description
0-0.4	SAND – grey, low organic matter, fine-grained, medium density.
0.4-0.6	SAND– as above, little to no organic material, intermixed with ironstone nodules (5-10mm, ~30%/volume).
>0.6	SANDY CLAY – mottled orange-grey-brown, stiff, intermixed with ironstone nodules (5-10mm, ~5%/volume).

4.7 Hydrogeology

4.7.1 Aquifers

A review of the Victorian Groundwater Beneficial Use Map Series – South Western Victoria Water Table Aquifers (DCNR, 1995) indicates that groundwater beneath the Site occurs within the Upper Tertiary Aquifer.

4.7.2 Groundwater Quality

The quality of groundwater in Victoria is protected under the *State Environment Protection Policy Groundwaters of Victoria* (SEPP GoV), subordinate legislation to the *Environment Protection Act* 1970. The SEPP GoV defines a number of segments and protected beneficial uses of groundwater based on the background level of Total Dissolved Solids (TDS).

Groundwater is expected to contain a Total Dissolved Solids (TDS) concentration between 1,001 mg/L and 3,500 mg/L (Segment B), (DCNR, 1995).

4.7.3 Groundwater Flow System

Based on the topography of the Site and the surrounding area, the groundwater within the local aquifer system is expected to flow to the northeast towards Watsons Creek (approximately 2km northeast of the Site).

4.7.4 Regional Groundwater Use

Atma undertook a search of the Department of Sustainability and Environment (DSE) Groundwater Database which is documented in Section 3.6 of the Atma PESA. The DSE Groundwater Database search found that there are no registered groundwater bores located within a 3km radius of the Site.

5.0 Beneficial Uses

5.1 Land

5.1.1 Regulatory Framework

State Environment Protection Policy - Prevention and Management of Contamination of Land, 2002 SEPP (PMCL) sets out the regulatory framework for the prevention and management of contamination of land within the State of Victoria. The goal of the policy is:

> *"to maintain and where appropriate and practicable improve the condition of the land environment sufficient to protect current and future beneficial uses of land from the detrimental effects of contamination by:*
>
> - preventing contamination of land; and
> - where pollution has occurred, adopting management practices that will ensure:
>   - unacceptable risks to human health and the environment are prevented; and
>   - pollution is cleaned up or otherwise managed to protect beneficial uses."

The SEPP (PMCL) identifies land use categories and protected beneficial uses for each of these categories. Land (principally soil) is considered polluted where relevant protected beneficial uses for the relevant land use categories are precluded. Beneficial uses of land are considered precluded when relevant land quality objectives set out in the SEPP (PMCL) have been exceeded.

5.1.2 Likely Land Uses

A future use of the Site is yet undetermined. For the purposes of this audit, based on the surrounding land use as well as land use sensitivity, it is likely that the Site could be redeveloped into a low-density residential use.

As defined in the SEPP (PMCL), the land use of the Site can be categorised as 'Sensitive Use – Other'. A sensitive use as defined in the SEPP (PMCL) is:

> *"means a residential use, a child care centre, a pre-school centre or a primary school as defined in Minister's Direction No.1 as amended from time to time under section 12(2)(a) of the Planning and Environment Act 1987".*

Under Clause 9(1)(c) of the SEPP (PMCL) the sensitive use category of land use defines that sensitive use may occur in an area of High density (where development makes maximum use of available land space and there is minimal access to soil) or in Other lower density areas (where there is generally substantial access to soil).

5.1.3 Protected Beneficial Uses

All protected beneficial uses of land must be considered when undertaking a contaminated land environmental audit and when determining whether to issue a Certificate of Environmental Audit. In accordance with the SEPP (PMCL) they are:

- Maintenance of ecosystems,
- Human Health,
- Buildings and Structures,

- Aesthetics, and
- Production of Food, Flora and Fibre.

In the context of the proposed residential development, all of these beneficial uses of the land are considered relevant and require protection.

5.1.4 Soil Quality Objectives

In accordance with the SEPP (PMCL), soil quality objectives for the beneficial uses were primarily sourced from the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPC, 1999) ('the NEPM'), specifically those provided in Schedule B(1) of the NEPM, *Guideline on the Investigation Levels for Soil and Groundwater*. The specific objectives used for each protected beneficial use identified in **Section 5.1.3** are described in the following sections.

Maintenance of Ecosystems

Schedule B(1) of the NEPM provides a range of investigation levels for the protection of ecosystems, referred to as Ecological Investigation Levels (EILs). The following should be noted:

- A limited range of EILs is provided, and only for metals/metalloids (regional-based EILs are currently not available). These values are based on consideration of phytotoxicity, 'ANZECC B' levels (ANZEC/NHMRC, 1992) and soil survey data from urban residential properties in four Australian capital cities; and
- The EILs do not currently discern between natural, modified and highly modified ecosystems, as defined in the SEPP (PMCL).

EILs have been used to assess the suitability of the Site for the maintenance of ecosystems (modified and highly modified ecosystems) beneficial use, by direct comparison with soil concentrations found at each sampling location (refer to **Section 6.3**).

Human Health

Schedule B (1) of the NEPM provides a range of investigation levels for the protection of human health, referred to as Health Investigation Levels (HILs). HILs are provided for four exposure settings based on land use. These are:

- Setting A - 'Standard' residential with garden/accessible soil (home-grown produce contributing less than 10% of vegetable and fruit intake; no poultry). This category includes children's day-care centres, kindergartens, preschools and primary schools.
- Setting D – Residential with minimal opportunities for soil access. Includes dwellings with fully and permanently paved yard space such as high-rise apartments and flats.
- Setting E – Parks, recreational open space and playing fields. Includes secondary schools.
- Setting F – Commercial/industrial. Includes premises such as shops and offices as well as factories and industrial sites.

It is emphasised within the NEPM that HILs are not intended for use as default remediation trigger criteria, but are actually intended to prompt an appropriate site-specific assessment when they are exceeded.

Given that the Site is proposed to be used for residential purposes, the Setting A HILs have been used for comparison against the soil results.

Where Setting A HILs are not available for some chemicals of concern, the following threshold criteria have been used:

- For Total Petroleum Hydrocarbons (TPH), NSW EPA Guidelines for Assessing Service Station Sites, 1994 are used. Where TPH exceed the threshold concentration of 1,000 mg/kg TRH (C_{10}-C_{36}), further analysis of speciated hydrocarbons may be undertaken which are directly comparable with published HILs for that analysis.
- As there is no NEPM 1999 HIL for vanadium, the Dutch Indicative Level for Serious Contamination (Dutch ILSC) has been used (i.e. 250 mg/kg).

Under normal circumstances, HILs are to be applied in the following manner:

- average (arithmetic mean) soil concentrations across the Site should be compared to the investigation levels;
- no single sample concentration is to exceed 250% of its respective investigation level; and
- the standard deviation of the concentrations for a given chemical is to be less than 50% of its investigation level.

Accordingly, HILs have been used to assess the suitability of the Site for its intended land use by consideration of these statistical parameters as well as by direct comparison with individual soil concentrations found at each sampling location (refer to **Section 6.3**).

Buildings and Structures

The SEPP (PMCL) states, "Contamination must not cause the land to be corrosive to or adversely affect the integrity of structures or building materials". No soil quality objectives have been adopted in the assessment of this beneficial use. The potential for the condition of soils at the Site to adversely impact upon buildings and structures is discussed in **Section 6.3**.

Aesthetics

The SEPP (PMCL) states, "Contamination must not cause the land to be offensive to the senses of human beings". The aesthetic quality of soils at the Site is discussed in **Section 6.3**.

Production of Food, Flora and Fibre

The SEPP (PMCL) states, "*Contamination of land must not:*

a. Adversely affect produce quality or yield; and
b. Affect the level of any indicator in food, flora and fibre produced at the Site (or that may be produced) such that the level of that indicator is greater than that specified by the Australia New Zealand Food Authority Food Standards Code. "

Soil quality objectives are not currently available for the protection of this beneficial use. In their absence, NEPM EIL guideline values have been used to assess this beneficial use.

5.2 Groundwater

State Environment Protection Policy (Groundwaters of Victoria), 1997 (SEPP (GoV)) sets out the regulatory framework for the protection of groundwater in the State of Victoria. The goal of the policy is:

"to maintain and where necessary improve groundwater quality sufficient to protect existing and potential beneficial uses of groundwaters throughout Victoria"

The SEPP (GoV) defines a range of protected beneficial uses for defined segments of the groundwater environment. The segments are based on groundwater salinity (Total Dissolved Solids). Groundwater is considered polluted where the objectives for indicators of a beneficial use are exceeded, or where non-aqueous phase liquid is present. Where groundwater has been polluted it must be cleaned up such that the protection of beneficial uses is restored, or if this is not possible, groundwater must be cleaned up to the extent practicable.

As indicated in section 4.7.2 groundwater is expected to contain a Total Dissolved Solids (TDS) concentration between 1,001 mg/L and 3,500 mg/L (Segment B), (DCNR, 1995).

The beneficial uses of groundwater to be protected under Segment B and groundwater quality objectives (as defined under SEPP GoV) include the following:

- maintenance of ecosystems;
- potable mineral water supply;
- agriculture, parks and gardens;
- stock watering;
- industrial water use;
- primary contact recreation; and
- buildings and structures.

The Auditor has considered the potential for pollution of groundwater at the Site, or arising from the Site, in accordance with Section 13 of the auditor guidelines (i.e. EPA Publication 759.1). On this basis, the Auditor did not consider that groundwater is likely to be polluted, based on the following:

- There were no on-site sources of groundwater contamination identified on the Site (refer to **Section 6.1.1**).
- No off-site sources of groundwater pollution were identified (refer to **Section 6.1.2**.

As such no further assessment of groundwater was considered warranted.

6.0 Contamination Assessment

6.1 Potential Sources of Contamination

6.1.1 On-Site Sources

On the basis of historical information (**Section 4.1**) and observations made during Site investigations, the primary sources of contamination from the Site are considered to be as follows:

Potential Sources of Contamination	Chemicals of Potential Concern
Former rail use	A range of potential contaminants may be present in soil due to rail use activities, including fuels, oils, pesticides and metals
Vacant land occasionally used for a car park	Fuels and oils
Historical water hole	Chemicals associated with backfill material
Possible orchard	Pesticides
Possible vineyard	Pesticides
Stockpile of fill material (ballast) near Southern boundary	A range of potential contaminants may be present in the soil beneath including fuels, oils, solvents, and metals

6.1.2 Off-Site Sources

No off-site contamination sources were identified during the assessment that may have the potential to pollute the Site.

6.1.3 Groundwater

As discussed in **Sections 5.2**, no sources of groundwater pollution were identified and no further assessment of groundwater was considered warranted.

6.2 Nature and Extent of Contamination

6.2.1 Soil Investigations Undertaken

All soil investigation results are detailed within the Atma PESA (**Attachment 1**) and the Atma ESA (**Attachment 2**). Field investigations were conducted at the Site on 2 August 2006 and 24 January 2007.

Soil samples were collected from various depths within the fill and underlying natural material to a maximum depth of 1.6 mbgs. Samples were collected within the identified soil strata and not across the interface of two or more different soil strata. PESA works were completed prior to the engagement of an Auditor and samples were obtained by hand auger as described in the Atma PESA (**Attachment 1**). Eight sample locations were placed in a grid formation and were sampled for EPA Publication 448.1 Screen (note: now screens are EPA 448.3), plus composite samples for organochlorine pesticides (OCPs) and polycyclic aromatic hydrocarbons (PAHs). In addition, four locations were composited targeting the green waste stockpile on the Site and analysed for an EPA Publication 448.1 Screen. Further information on the analytical suite can be found in **Table 3** of the Atma PESA (**Attachment 1**).

Following removal of the green waste additional ESA samples were obtained by backhoe during the fieldworks described in the Atma ESA (**Attachment 2**). Eight additional grid locations plus two targeted locations (one under where green waste stockpiles had been, and one in former ballast) were sampled and analysed for an EPA Publication 448.2 Screen. In addition, all samples which were being held by the laboratory from the first stage of results were analysed for vanadium and arsenic if they had not been analysed previously. The green waste stockpiled material was also removed from the Site during this stage of works.

Soil sampling locations are shown on **Figure 1** of the Atma ESA (**Attachment 2**).

Samples were placed in appropriately washed jars supplied by the laboratories, and in plastic sealable bags for on-Site VOC screening using an Eagle Portable Gas Detector.

6.2.2 Soil Contamination Present

The following table provides a summary of chemicals of concern whose concentrations in soils remaining on the Site exceed the adopted soil quality objectives:

Chemical	Sampling Depth Range (mbgs)	Total No. of Samples Analysed	Concentration Range	No. of Samples with Chemical Concentrations Above Soil Quality Objectives	Soil Quality Objectives Exceeded	
					Type	Concentration (mg/kg)
Vanadium	0.1–1.0 mbgs	29	<10–220 mg/kg	19	EIL	50 mg/kg
Vanadium Composites	-	3	47 – 93 mg/kg	3	EIL	17 mg/kg1
Vanadium Composites	-	3	47 – 93 mg/kg	1	Dutch ILSC	83 mg/kg1
Arsenic	0.1–1.0 mbgs	29	<2 – 110 mg/kg	7	EIL	20 mg/kg
Arsenic	0.1–1.0 mbgs	29	<2 – 110 mg/kg	1	HIL A	100 mg/kg
Arsenic Composites	-	6	<2 – 47 mg/kg	1	EIL	7 mg/kg1
Arsenic Composites	-	6	<2 – 47 mg/kg	1	HIL A	33 mg/kg1

Note: 1 – Soil quality objective has been adjusted by dividing the objective by the number of samples making up the composite. In all cases three-part composities were collected.

6.3 Impacts on Beneficial Use

Based on the SEPP (PMCL) and results of the Atma PESA in **Attachment 1** and the Atma ESA in **Attachment 2**, the impacts on the following beneficial uses of land at the Site are detailed in the following table:

Beneficial Use	Beneficial Use Potentially Precluded?	Comment/Rationale
Maintenance of Ecosystems	No	Vanadium and arsenic concentrations across the Site exceeded EILs. The Auditor sought expert advice from Dr. Robert van de Graaff on the origin on these exceedences and bioavailability. In Dr. van de

Beneficial Use	Beneficial Use Potentially Precluded?	Comment/Rationale
		Graaff's report provided as **Appendix D**, he concludes that the arsenic and vanadium at the Site does not pose an unacceptable environmental risk due to their natural origin within the prevailing geological conditions at the Site (and the region) and low bioavailability.
Human Health	No	In compliance with the NEPC guidelines, the average (arithmetic mean) of the arsenic concentrations across the Site (23.9 mg/kg) is less than its HIL A. However, the concentration of arsenic exceeded the HIL A in two samples (i.e. 110 mg/kg in sample BH18/0.5 and 290 mg/kg in sample BH8/0.5). The concentration of arsenic exceeds the HIL A by greater than 250 %, however these concentrations are not considered to pose an unacceptable risk due to their relatively isolated occurrence, the fact that they are within natural material at 0.5 m depth and are of natural origin with expected low bioavailability as stated in Dr van de Graaff's report provided as **Appendix D**.
Buildings and Structures	No	To determine the protection of the Buildings and Structures beneficial use, surface soil results for sulphate (SO_4) were compared to Table 6.3 in AS2159-1995 Piling – Design and Installation. These results ranging from 16 to 140 mg/ kg were well below the non-aggressive soil exposure classification criteria of 2,000 mg/kg.
Aesthetics	No	It was noted that there were no odours in the soils while sampling. In addition, there was no fill material noted to remain on the Site (i.e. which may have potentially been visually offensive).
Production of Food, Flora and Fibre	No	The NEPC EIL criteria were used to determine the preclusion of this beneficial use, therefore the same outcome as determined for the Maintenance of Ecosystems Beneficial Use described above applies.

6.4 Risk Evaluation

6.4.1 Human Health Risk

As discussed in **Section 6.3**, the condition of the land (in terms of residual chemical contamination) is not considered to pose an unacceptable human health risk.

6.4.2 Environmental Risk

As discussed in **Section 6.3**, the condition of the land (in terms of residual chemical contamination) is not considered to pose an unacceptable environmental risk.

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7.0 Quality of Information

7.1 Historical Information

Guidance on undertaking historical reviews for the purposes of identifying potential land contamination issues of a Site and surrounding land is provided in the following documents:

- AS 4482.1-2005, Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 1: Non-volatile and Semi-volatile Compound.
- National Environment Protection Council (NEPC), 1999, Guideline on Data Collection, Sample Design and Reporting (Schedule B (2)), National Environment Protection (Assessment of Site Contamination) Measure.

Relevant historical information pertaining to the Site is documented in the Atma PESA (**Attachment 1**) and Atma ESA (**Attachment 2**). The sources of historical information included the following:

- Historical information from VicTrack;
- List of Issued Certificates and Statements of Environmental Audit from EPA Victoria;
- EPA Victoria's Priority Sites Register;
- Historical Aerial Photographs; and
- Historical Certificates of Title.

The Auditor is satisfied that the appropriate and available sources of historical information were reviewed and that an adequate understanding of the previous activities undertaken at the Site has been obtained for the purposes of this audit.

7.2 Soil Investigation Methodology and Results

Guidance on undertaking field investigations for the purposes of undertaking an environmental site assessment is provided in the following documents:

- *State environment protection policy* (Prevention and Management of Contamination of Land)
- AS 4482.1-2005, Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 1: Non-volatile and Semi-volatile Compounds
- AS 4482.2-1999, Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 2: Volatile Substances
- National Environment Protection Council (NEPC), 1999, Guideline on Data Collection, Sample Design and Reporting (Schedule B (2)), National Environment Protection (Assessment of Site Contamination) Measure
- Environment Protection Authority, 2000, A Guide to the Sampling and Analysis of Waters, Wastewaters, Soils and Wastes, EPA Publication 441.7

Soil investigations undertaken by Atma are described in the Atma PESA (**Attachment 1**) and Atma ESA (**Attachment 2**).

Primary components of a field investigation relevant to this audit, together with the Auditor's observations comments in relation to works conducted by Atma, are summarised as follows:

Component of Field Investigation	Auditor's Observations and Comments
Soil sampling coverage	The sampling coverage was sufficient for the Auditor to form an opinion on the nature and extent of contamination at the Site. The sampling coverage consisted of 17 locations based roughly on a square grid-based pattern. This sampling density meets the minimum sampling density recommended within AS4482.1, for a site of this size (based on a square grid systematic sampling pattern for the detection of circular hot spots). It is noted that the actual sampling pattern is not precisely square, however the Auditor is satisfied that the sampling density is adequate for this particular Site.
Sample collection techniques	During the fieldworks conducted as part of the Atma PESA (Attachment 1), soil samples collected from the locations were taken directly from the hand augers with disposable nitrile gloves, which is an acceptable technique for analytes of interest except volatile chemicals. These works were completed prior to the engagement of the Auditor. During the fieldworks conducted as part of the Atma ESA (Attachment 2), the soil samples were taken from the bucket of a backhoe. Although hand auger techniques used previously are not acceptable for sampling potentially volatile impacted soils according to AS4482.2, the Auditor notes that the analytical results are similar for each stage of work (i.e. volatile chemicals were not detected) and therefore the presence of volatile chemicals at the Site is considered unlikely.
Sampling equipment decontamination	Hand auger equipment used for the collection of the soil samples was washed with detergent and thoroughly rinsed with clean water between locations. Test pit additional samples were collected from soil that did not contact the excavator bucket and did not require decontamination.
Field measurements	A split of all soil samples collected was screened using an Eagle Portable Gas Detector. Calibration certificates for the operation of the Eagle Portable Gas Detector were obtained and are attached in Appendix H of the Atma PESA (Attachment 1) and Appendix D of the Atma ESA (Attachment 2).
Field documentation (i.e. field notes, bore logs and chain-of-custody records)	All field documentation was completed to a satisfactory standard to enable the Auditor to interpret the data. The Auditor and/or his representative observed field documentation being completed during investigations.
Sample handling, preservation and storage	Soil samples were collected in jars supplied by the laboratory and stored/transported in chilled eskies. The Auditor's representative observed these procedures and noted that they were consistent with the referenced guidelines.
Number and type of quality control samples	The Auditor considered that the number and type of QC samples collected during the audit was sufficient. QC samples were collected at the recommended frequency. Blind and spilt duplicate samples were collected and analysed at a frequency of at least one for every 20 soil samples collected. Most of blind and duplicate samples were within the acceptable limits of relative percentage differences (RPDs). RPDs were higher than acceptable limits where concentrations were relatively low, where small differences in concentration return relatively high RPDs. A trip, field and rinsate blank were held at the lab to be sampled if gross contamination was found at the Site or if any results were questionable.

Component of Field Investigation	Auditor’s Observations and Comments
	One rinsate blank was analysed for metals during the Atma PESA and did not report any concentrations above the level of reporting. Based on the results obtained, the analysis of the remaining trip, field and rinsate blanks was not required.
Laboratory quality control analysis results	The laboratory used analysed a series of internal matrix spikes, supplicates and blanks at the appropriate frequencies. These analyses returned acceptable results. The primary and secondary laboratories used NATA accredited test methods.
Selection of chemical analytes	The range of chemical analytes selected for analysis was considered appropriate given the history of the Site and the potential contamination issues identified.

7.3 Auditor’s Assessment of Adequacy

In summary, enough sampling was undertaken to provide the Auditor with assurance regarding the quality of the data and to form an opinion on the contamination status of the Site. In the Auditor’s opinion, the quality and reliability of information generated from the investigations undertaken (taking into account all limitations as identified in previous sections) was sufficient for the purposes of this environmental audit.

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8.0 Conclusions

The conclusions of this environmental audit can be summarised as follows:

- Based on review of historical information and Site inspection, the Site was historically vacant land used for a car park, as well as rail use. It was also possibly used as an orchard, vineyard and for sheep grazing.
- Soil analytical results indicated contamination concentrations to be below the human health investigation levels for residential land use for all sample locations, except two samples (110 mg/kg in sample BH18/0.5 and 290 mg/kg in sample BH8/0.5). The concentration of arsenic exceeds the HIL A by greater than 250%, however these concentrations are not considered to pose an unacceptable risk due to their relatively isolated occurrence, the fact that they are within natural material at 0.5 m depth and are of natural origin with expected low bioavailability as stated in Dr van de Graaff's report provided as **Appendix D**.
- Similarly, soil analytical results indicated concentrations for vanadium and arsenic which exceeded ecological investigation levels. However, expert advice from Dr. Robert van de Graaff, concludes that the arsenic and vanadium at the Site are likely to be consistent with conditions for ecosystems in the area and does not pose an unacceptable environmental risk.
- In the Auditor's opinion, the quality and reliability of information generated from the investigations undertaken were sufficient for the Auditor to form an opinion on the environmental condition of the Site.

As all protected beneficial uses of the land a protected, a Certificate of Environmental Audit has been issued for the Site. The Certificate of Environmental Audit is provided as **Appendix B**.

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9.0 Limitations

This audit report and attached Certificate of Environmental Audit were prepared for VicTrack in accordance with Part IXD of the *Environment Protection Act* 1970.

In reaching their conclusions about the Site, VicTrack, Mornington Peninsula Shire Council and EPA Victoria may use this audit report and Certificate of Environmental Audit. The scope of work performed as part of the audit process may not be appropriate to satisfy the needs of any other person. Any other person's use of, or reliance on, the audit document and report, or the findings, conclusions, recommendations or any other material presented to them, is at that person's sole risk.

The audit is based on a review of the condition of the Site at the time of assessment, as described in the assessment reports attached to the audit report and site inspections conducted by the Auditor and his representatives.

The audit and this report are limited by and rely upon the review's scope, the information provided by VicTrack and Atma, through the documents provided to the Auditor. The Auditor used reasonable care to avoid reliance upon data and information that may be inaccurate. The Auditor's conclusions presented in this report are therefore based on the information made available to him and on his own observations during the audit. These conclusions may be different if the information upon which they are based is determined to be false, inaccurate or incomplete.

The Auditor notes that subsurface conditions can vary over short distances and it is possible that small areas of contaminated soil may not have been detected between the sampling points.

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10.0 References

Atma Environmental Pty Ltd, Environmental Site Assessment, Lot 38, Somerville Victoria, 7 December 2006.

Atma Environmental Pty Ltd, Preliminary Environmental Site Assessment, Lot 38, Somerville Victoria, 23 April 2007.

Department of Conservation and Natural Resources (DCNR, 1995), Victorian Groundwater Beneficial Use Map Series, South Western Victoria Water Table Aquifers.

Environment Protection Authority (EPA, 1997). State Environment Protection Policy S160 Groundwaters of Victoria. Government Gazette, Victoria.

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Environment Protection Authority Guidelines (EPA publication 759b, June 2002). Environmental Auditor (Contaminated Land) Guidelines for Issue of Certificates and Statements of Environmental Audit. Environment Protection Authority Victoria.

National Environment Protection Council (NEPC, 1999). National Environment Protection (Assessment of Site Contamination). Measure. Schedule B(1), Guideline Investigation Levels Soil and Groundwater. December 1999.

National Health and Medical Research Council, Agriculture and Resource Management Council of Australia and New Zealand (NHMRC, 1996). Australian Drinking Water Guidelines.

Standards Australia (AS, 2005). Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 1: Non-Volatile and Semi-Volatile Compounds. Publication AS 4482.1 – 1997.

Standards Australia (AS, 1999). Guide to the Sampling and Investigation of Potentially Contaminated Soil, Part 2: Volatile Substances. Publication AS 4482.2 – 1999.

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11.0 Abbreviations

AMG	Australian map grid
AS	Australian Standard
AST	Aboveground storage tank
ANZECC	Australian and New Zealand Environment and Conservation Council
BTEX	Benzene, toluene, ethyl benzene, xylenes
COC	Chain of custody
DO	Dissolved oxygen
EC	Electrical conductivity
EIL	Ecological Investigation Level
ESA	Environmental Site Assessment
HIL	Health Investigation Level
m bgs	metres below ground surface
MAHs	Monocyclic aromatic hydrocarbons
NATA	National Association of Testing Authorities
NEPM	National Environment Protection Measure
OCP	Organochlorine pesticides
OPP	Organophosphorus pesticides
PAHs	Polycyclic aromatic hydrocarbons
PCR	Primary Contact Recreation
PID	Photo-ionisation detector
RPD	Relative percentage difference
SEPP	State Environment Protection Policy
SVOCs	Semi-volatile organic compounds
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
UST	Underground storage tank
VOCs	Volatile organic compounds

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Figures

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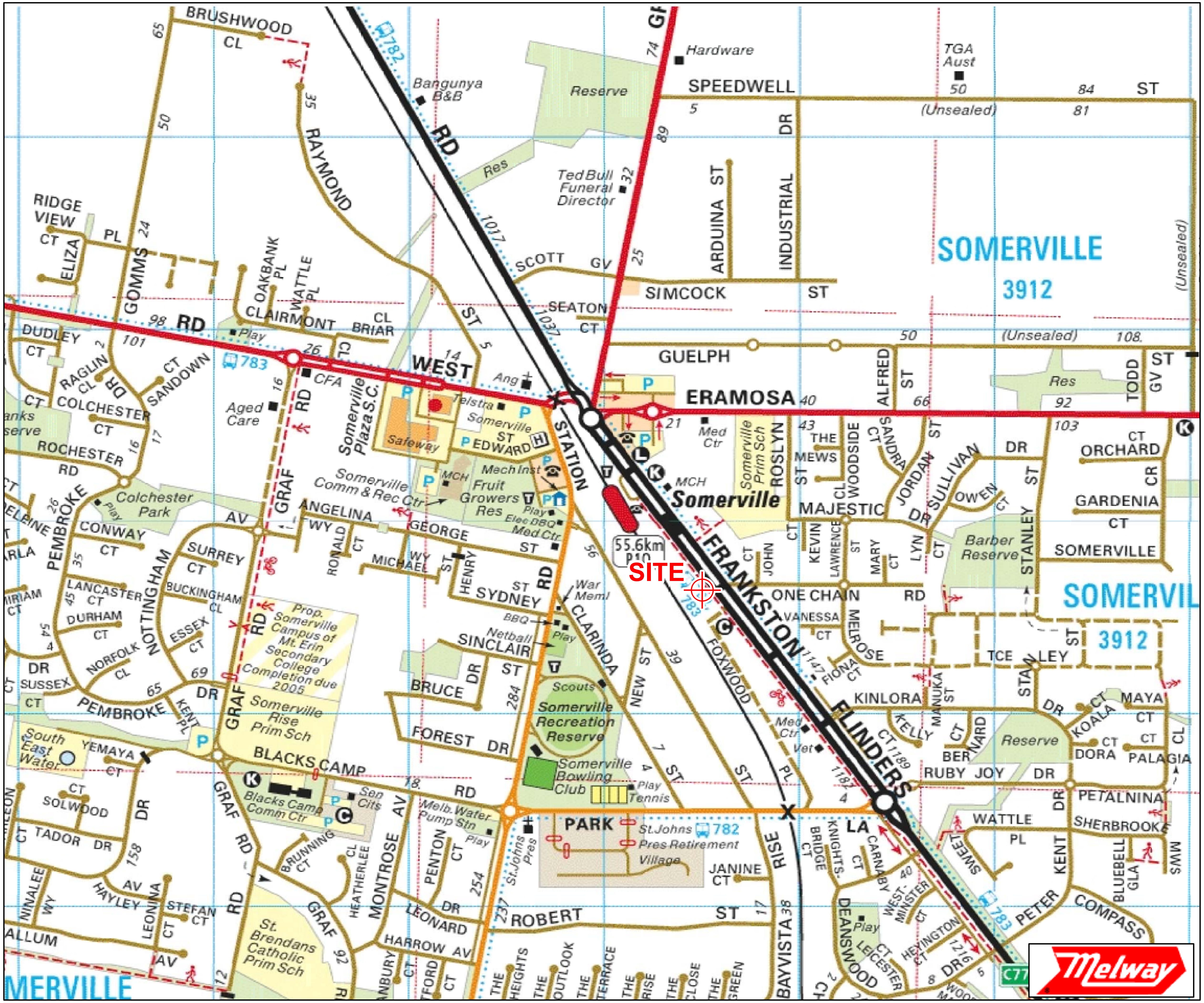

PROJECT ID M4054801
DATE CREATED 08 October 2007
DRAWN BY ART
LAST MODIFIED ART 08 October 2007
APPROVED

Legend

Approximate Scale

0 68 125 188 250

Metres

ENSR | AECOM

HLA Merged with ENSR in 2007

Figure

1

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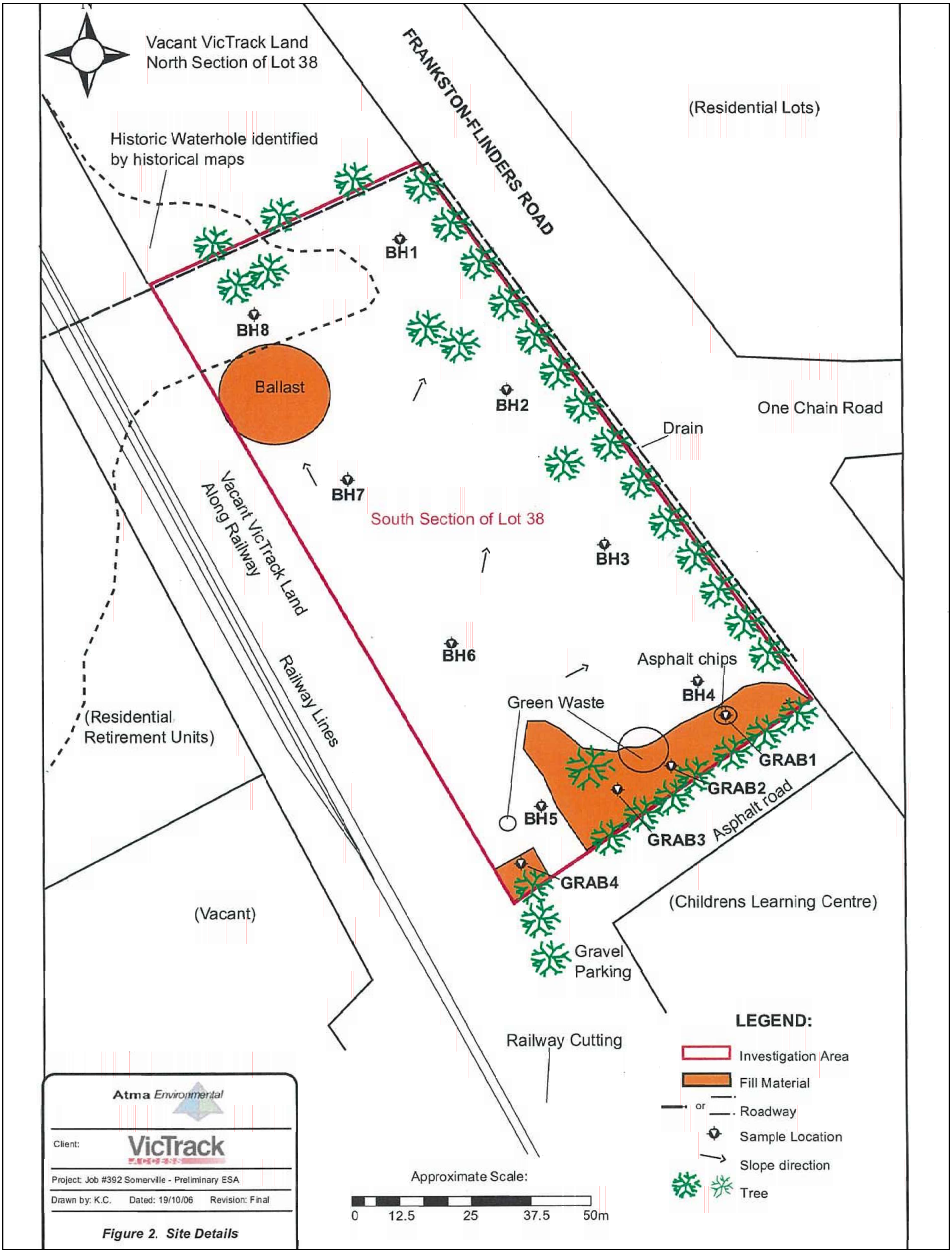

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ENSR | AECOM

HLA Merged with ENSR in 2007

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 35 70 140 210 280

Metres

FIGURE

2

PROJECT ID M4054801 DATE DRAWN 08 Oct 07 DRAWN BY ART LAST MODIFIED ART 08 Oct 07 APPROVED

Appendix A: Executive Summary

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Table 1: Summary of Audit Information

Summary Information Required	
EPA file reference number	61006-1
Auditor	Michael Seignior
Auditor term of appointment	Initial appointment: 4 March 2003 Current appointment: 3 March 2007 – 2 March 2009
Name of person requesting audit	Mr. Stephen Hamilton
Relationship to premises	Employee of owner (VicTrack)
Date of request	21 September 2006
Date EPA notified of audit	26 September 2006
Completion date of audit	12 December 2007
Reason for audit	Divestment of property
Current land use zoning	Public Use (Transport) Zone (PUZ4), Crown Land
EPA region	South Metro
Municipality	Mornington Peninsula Shire
Dominant – Lot on plan	Vol 09974 Fol 846
Additional – Lot on plan(s)	N/A
Site/premises name	VicTrack Somerville
• Building/complex subunit no.	
• Street/Lot – lower no.	Southern portion of Lot 38
• Street/Lot – upper no.	
• Street Name	Frankston-Flinders
• Street Type	Road
• Street Suffix	
• Suburb	Somerville
Postcode	
GIS coordinates of site centroid • Latitude	340502E
• Longitude	5767432N
Site area (hectares)	0.8 ha
Members and categories of support team utilised	Dr. Robert van de Graaff, soil science
Outcome of audit	Certificate
Further work requirements	None
Nature and extent of continuing risk	None

Table 2: Physical Site Information

Summary Information Required	
Site aquifer information	Upper Tertiary Aquifer (DCNR, 1995)
Average depth to groundwater	Unknown
Groundwater segment	Segment B (DCNR, 1995)
Groundwater flow direction	Anticipated to head to northeast
Past use/site history	Rail use, car park
Surrounding land use	Commercial and Residential
Proposed future use	N/A

Appendix B

Certificate of Environmental Audit

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ENVIRONMENT PROTECTION ACT 1970

CERTIFICATE OF ENVIRONMENTAL AUDIT

I, Michael Seignior of ENSR Australia Pty Ltd, a person appointed by the Environment Protection Authority ('the Authority') under the *Environment Protection Act 1970* ('the Act') as an environmental auditor for the purposes of the Act, having:

1 been requested by Stephen Hamilton (Victorian Rail Track Access) to issue a certificate of environmental audit in relation to the site located at the southern portion of Lot 38, Frankston-Flinders Road, Somerville, Victoria, described as Vol 09974 Fol 846, in the Parish of Tyabb, Mornington Penninsula Shire ('the site') owned/occupied by Victorian Rail Track Access.

2 had regard to, among other things,

a) guidelines issued by the Authority for the purposes of Part IXD of the Act,

b) the beneficial uses that may be made of the site, and

c) relevant State environment protection policies (SEPPs) and industrial waste management policies (IWMPs), namely;

SEPP (Groundwaters of Victoria), 1997;
SEPP (Prevention and Management of Contamination of Land), 2002; and
IWMP (Prescribed Industrial Waste), 2000.

in making a total assessment of the nature and extent of any harm or detriment caused to, or the risk of any possible harm or detriment which may be caused to, any beneficial use made of the site by any industrial processes or activity, waste or substance (including any chemical substance), and

3 completed an environmental audit report in accordance with section 53X of the Act, a copy of which has been sent to the Authority and the relevant planning and responsible authority.

HEREBY CERTIFY that I am of the opinion that the condition of the site is neither detrimental nor potentially detrimental to any beneficial use of the site.

Other related information: Nil

This Certificate forms part of environmental audit report (ENSR Australia Pty Ltd, Environmental Audit Report, Southern Portion of Lot 38, Frankston-Flinders Road, Somerville, Victoria: M4054801_R001_12Dec07, dated 12 December 2007). Further details regarding the condition of the site may be found in the environmental audit report.

DATED: 12/12/2007

Signed:

ENVIRONMENTAL AUDITOR

Appendix C

Certificate of Title and Title Plan

Security no : 124019398271C

Volume 09974 Folio 846
Produced 13/10/2006 10:06 am

LAND DESCRIPTION

Lot 1 on Title Plan 885734A (formerly known as part of Portion 19 Parish of Tyabb).
Created by Application No. 067851U 14/08/1990

REGISTERED PROPRIETOR

Estate Fee Simple
Sole Proprietor
VICTORIAN RAIL TRACK of 589 COLLINS STREET MELBOURNE 3000
V523041K 13/07/1998

ENCUMBRANCES, CAVEATS AND NOTICES

Any encumbrances created by Section 98 Transfer of Land Act 1958 or Section 24 Subdivision Act 1988 and any other encumbrances shown or entered on the plan set out under DIAGRAM LOCATION below.

Warning as to Dimensions
Any dimension and connecting distance shown is based on the description of the land as contained in the General Law Title and is not based on survey information which has been investigated by the Registrar of Titles.

DIAGRAM LOCATION

SEE TP885734A FOR FURTHER DETAILS AND BOUNDARIES

ACTIVITY IN THE LAST 125 DAYS

NIL

STATEMENT END

ORIGINAL

NOT TO BE TAKEN FROM THE OFFICE OF TITLES

VICTORIA

REGISTER BOOK

VOL. 9974 FOL. 846

Certificate of Title

UNDER THE "TRANSFER OF LAND ACT"

FOL.

VOL.

PUBLIC TRANSPORT CORPORATION of 60 Market Street Melbourne is the proprietor of an estate in fee simple subject to the encumbrances notified hereunder in all that piece of land in the Parish of Tyabb being part of Crown Portion 19 which land is shown enclosed by continuous lines on the map on the sheet annexed hereto- -

Dated 14/8/1990

DERIVED FROM APPLICATION 67851U

OFFICE OF TITLES VICTORIA

Assistant Registrar of Titles

ENCUMBRANCES

As to part of the land
Lease to Poultreymen & Farmers Trading Co (Somerville) Pty Ltd for term of 33 years from 18 April 1966 Deposited Deed No. 139786 (AP 67851U)

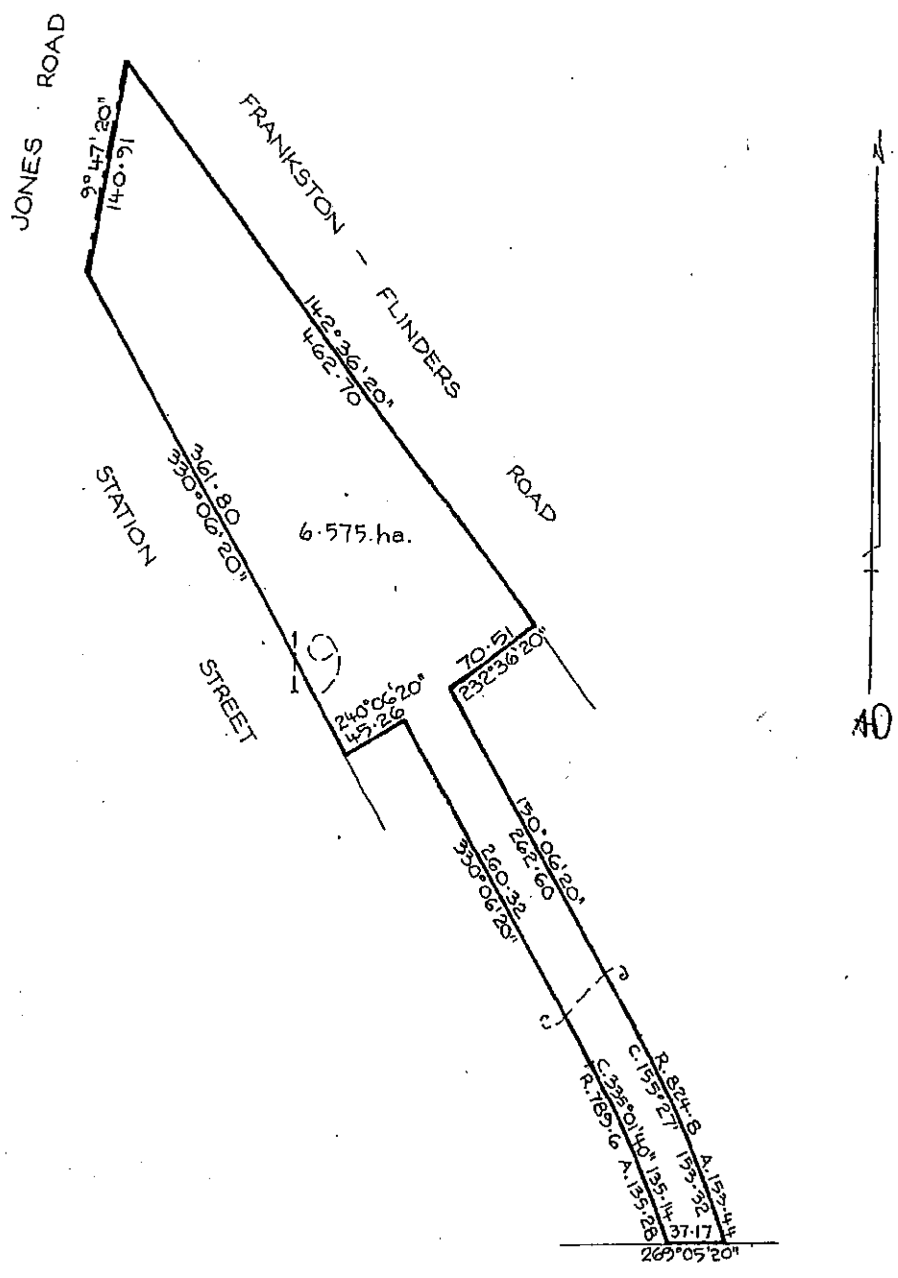
Warning as to Dimensions
Any dimension and connecting distance shown is based on the description of the land as contained in the General Law Title and is not based on survey information which has been investigated by the Registrar of Titles.

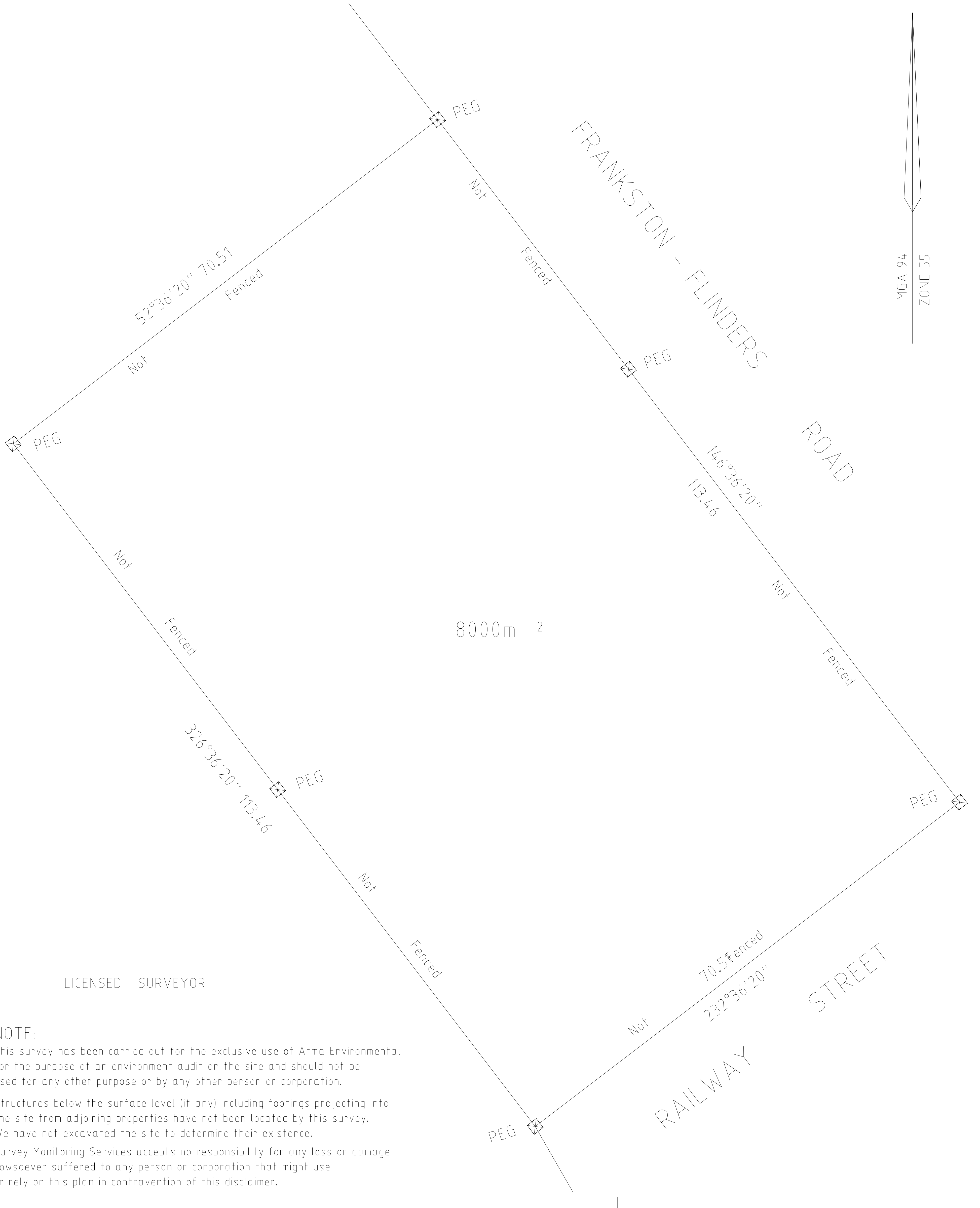
MEASUREMENTS ARE IN METRES

A. 57751 1st of 2

ANNEXED SHEET REFERRED TO IN
CERTIFICATE OF TITLE VOL. 9971 FOL. 846

ASSISTANT REGISTRAR OF TITLES





LICENSED SURVEYOR

NOTE:
This survey has been carried out for the exclusive use of Atma Environmental for the purpose of an environment audit on the site and should not be used for any other purpose or by any other person or corporation.

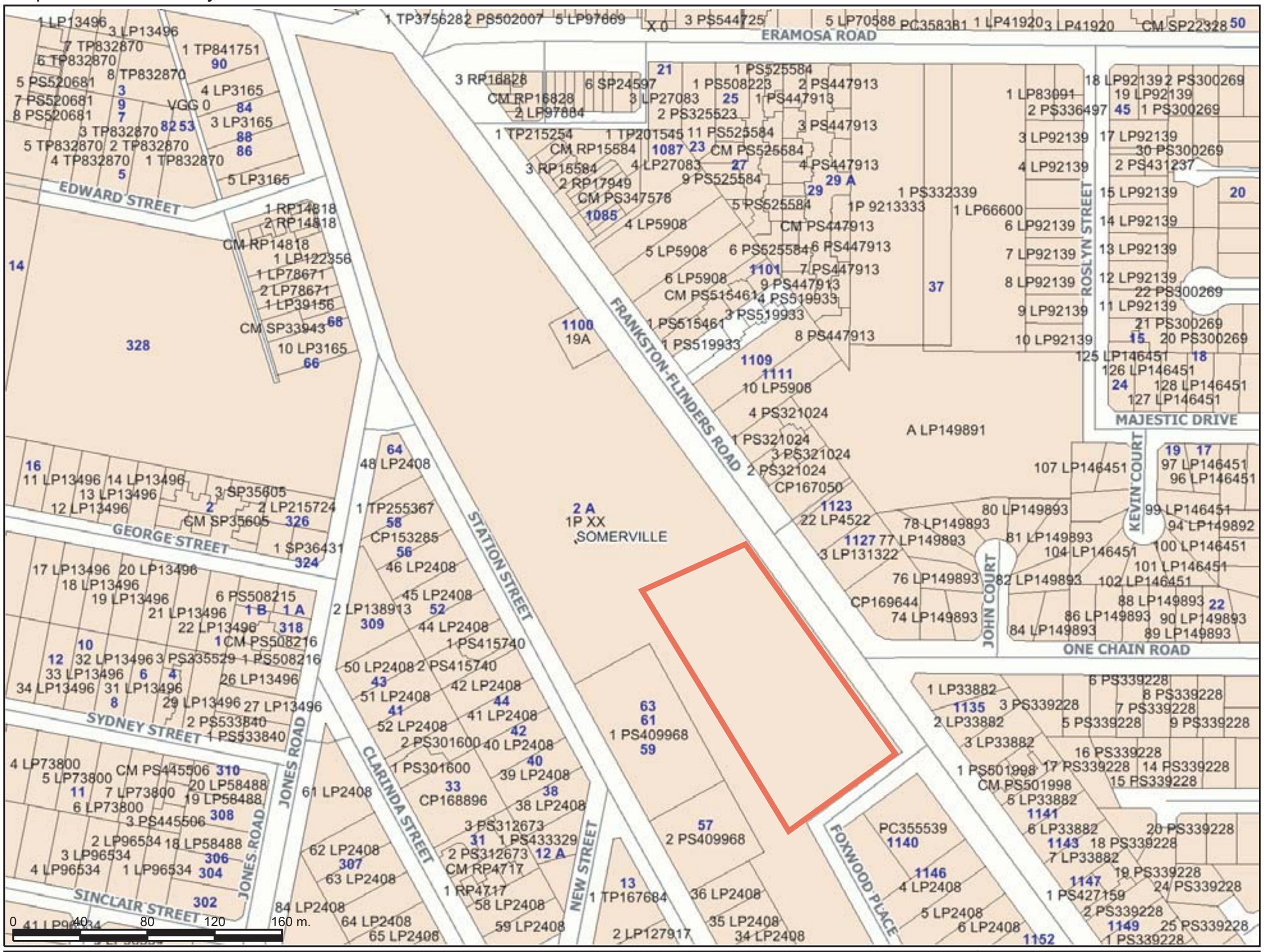
Structures below the surface level (if any) including footings projecting into the site from adjoining properties have not been located by this survey. We have not excavated the site to determine their existence.

Survey Monitoring Services accepts no responsibility for any loss or damage howsoever suffered to any person or corporation that might use or rely on this plan in contravention of this disclaimer.

LENGTHS ARE IN METRES DATE OF SURVEY: 21-12-2006 VERSION: 1	FRANKSTON - FLINDERS ROAD SOMERVILLE	PLAN OF ENVIRONMENT AUDIT AREA

SMS survey monitoring services P/L	13 Watersun Court, Sanctuary Lakes, VIC. 3030 Telephone: (0425) 700 060 Facsimile: (03) 9395 6624	SHEET 1 OF 1 SHEET	ORIGINAL SCALE 1:500
		ORIGINAL SHEET SIZE : A3	REF: 523

Department of Primary Industries



Legend

- Towns - detail
- Roads (vmtrans)
- Property - Parcel Description
- Crown Land
- Crown or Vested land
- Status of E, K or M - no shading
- Property - Address

Disclaimer: This map is a snapshot generated from Victorian Government data. This material may be of assistance to you but the State of Victoria does not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all liability for error, loss or damage which may arise from reliance upon it. All persons accessing this information should make appropriate enquiries to assess the currency of the data.

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NOT FOR NAVIGATION

GDA Vicgrid94

Victoria The Place To Be

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Appendix D

Dr. Robert van de Graaff Report

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Vanadium and Arsenic – Behaviour in Soils

and

Possible Impacts on Human Health and Vegetation

Case Study: Lot 38, Somerville, Victoria

for

HLA Envirosciences Pty Ltd

by

Robert H.M. van de Graaff, PhD
van de Graaff & Associates Pty Ltd
14 Linlithgow Street
Mitcham, VIC., 3132

(23 October 2007)

1. INTRODUCTION

HLA Envirosciences requested van de Graaff & Associates Pty Ltd to comment on the elevated vanadium concentrations found in soils at Lot 38, Somerville, Victoria, a site that was assessed by Atma Environmental Pty Ltd during 2006 and 2007 for soil contamination.

In addition, the request was more generally for assistance to determine a suitable alternative soil quality objective, as well as more detailed information on the chemical and physical properties of Vanadium in the soil, and how these might affect human exposure through speciation, bioavailability, etc.

2. SOIL CONCENTRATIONS OF VANADIUM AND ARSENIC AT LOT 38, SOMERVILLE

The data provided in the two reports by Atma Environmental show very clearly that the vanadium is associated with ferruginous material and has migrated through a geochemical process to the zones of the soil profile where iron compounds have accumulated. These are described in the bore logs as *"intermixed ironstone 4-6mm"*. It can be seen that arsenic and chromium and occasionally nickel are affected by the same geochemical process.

Lot 38 Somerville Round 1 Sampling 2 August 2006 - Heavy Metals

SAMPLE DEPTH	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8
0.1 m	As – 6.1 Cr – 9.2 Ni - <5 V - 31	As - <2 Cr - <5 Ni - <5 V - <10	As – <2 Cr – 5.2 Ni < 5 V – 11	As – <2 Cr 5.6 Ni - <5 V - <10	As – 5.5 Cr – 12 Ni 6.6 V – 14	As - <2 Cr - <5 Ni - <5 V - 10	As - <2 Cr – 6.5 Ni - <5 V – 12	As – 4.3 Cr – 6.7 Ni - <5 V – 16
0.5 m ***"intermixed ironstone 4-6mm" in all layers***	As – 82 Cr – 37 Ni - <5 V - 180	As - <2 Cr - <5 Ni < 5 V - <10	As - ,7.2 Cr – 33 Ni – 3.2 V - 67	As – 24 Cr – 42 Ni - <5 V - 120	As – 8.8 Cr – 23 Ni < 5 V - 51	As – 2.4 Cr - <5 Ni <5 V - 19	As – 17 Cr – 35 Ni – 8.3 V - 110	As – 290 Cr – 96 Ni - <5 V - 370

Lot 38 Somerville Round 2 Sampling 24 January 2007 - Heavy Metals

SAMPLE DEPTH	BH11	BH14	BH17	BH18
0.1 m	As – 2.0 Fe – 9500 V - 14	As - <2 Cr - <5 Ni - <5 V - <10		As – 7.9 Fe – 6400 V – 22
0.3m	As – 4.0 Fe – 22000 V - 58			
0.5 m	As - <2 Fe – 49000 V - 71	No analytical data	No analytical data	As – 110 Fe – 71000 V - 220
0.75 m	As – 2.2 Fe – 59000 V - 93			
1.0 m	As – 2.2 Fe – 26000 V - 70		As – 26 Fe --- V - 88	As – 64 Fe – 47000 V - 140

Yellow = Intermixed ironstone 4-6 mm present

The geochemical process illustrated by the bore logs and the laboratory data shows that if arsenic, chromium or nickel were present in significant concentrations, they will move to where the iron is being concentrated by extremely slow migration and precipitation. Iron is subject to changes in oxidation state due to periodic waterlogging and drying of the soil in the presence of organic matter. In its divalent state it is slightly more soluble than in its trivalent state.

The soils at Lot 38 are not described in the manner a soil scientist would describe them. . The bore log is constrained by the need for sampling at prescribed intervals, the surface at 0.1 m, at 0.5 m depth and at 1 m depth. It is clear that these soils are Duplex soils with a sharp increase in texture from the surface horizons, A1 and A2 horizons, to the subsoil, B horizon. The A1-A2 horizons are identified as "Sand", and the B horizon as "Sandy Clay". The A2 horizon probably starts at 0.3 m depth or less.

At the interface, in the lower part of the A2 horizon, due to the periodic fluctuations of redox potential the iron has formed ferruginous nodules, "buckshot", described by Atma Environmental as *"intermixed ironstone 4-6 mm"*. In this relatively shallow layer at the interface, the concentration of nodules ranges from 20-30% by volume. However, lower down in the B horizon there is still some 5% by volume of nodules. Apart from the nodules the colouration of the sandy clay with orange and red mottles shows that there is more iron that the iron in the nodules.

3. BEHAVIOUR AND ENVIRONMENTAL RISKS OF VANADIUM

Vanadium is an ubiquitous element in nature with an average concentration in the earth's crust of 110 – 150 mg/kg[1] and occurs naturally in igneous rocks, titaniferous magnetites (magnetite, Fe_3O_4), shales, some phosphatic rock, petroleum products and asphaltic deposits[2]. Crude oils can have up to 1400 mg/kg of vanadium. In man-made products, vanadium therefore occurs in rubber, and, as old rubber tyres are often used as fuel in cement kilns, vanadium often is significant in the exhaust gases of these kilns.

Vanadium can substitute for iron in iron oxides, as the ionic radius of V^{3+} is similar to that of Fe^{3+}, leading to high correlations between V and Fe contents of soils[3] and where B horizons have higher contents of clay and Fe oxides, the vanadium accumulates more in such horizons[4]. It is also widely distributed in biological materials as plants take it up, but there is generally no relationship between levels in plants and levels in the geological materials such as soils or rock. As vanadium rock minerals weather the vanadium is oxidised from V3+ within the mineral crystal lattice to V5+, the latter being more mobile depending on local soil physical and geochemical factors.[5]

Vanadium has seven oxidation states from -1, 0, +1, +2, +3, +4, and +5, the latter being the most toxic. It can occur in cationic and anionic form. Figure 1 is taken from Dragun[6] and illustrates the various species of vanadium in relation to pH and redox potential. Superimposed on the diagram are the outer boundaries of soil pH and soil redox potential found in natural soils.

---

[1] Adriano, D.C., (1986). Trace Elements in the Terrestrial Environment. Springer-Verlag, New York Inc.
[2] Irwin, R.J., van Mouwerik, M, Stevens, L., Seese, M.D., and Basham, W, (1997). Environmental Contaminants Encyclopedia – Vanadium Entry. National Park Service, Water Resources Division, Fort Collins, Colorado, USA.
[3] Norrish, K. (1975). The Geochemistry and Mineralogy of Trace Elements., In: Trace elements in soil-plant-animal systems. (Nicholas, D.J.D and Egan, A.R. (Eds), Academic Press, New York.
[4] Le Riche, H.H. and Weir, A.H. (1963). Trace elements in soil Fractions. J. Soil Science, Vol. 14, pp.225-235.
[5] Jones, K.C., Lepp, N.W., and Obbard, J.P., (1990). Other Metals and Metalloids. In: Alloway, B.J. (Ed.), Heavy Metals in Soils. Blackie, Glasgow & London.
[6] Dragun, James. (1998). The Soil Chemistry of Hazardous Materials. Amherst Scientific Publishers, Amherst, Massachusetts.

Organic matter plays an important role in cycling of vanadium, and humic acid has been shown to be able to reduce vanadate (V^{5+} ion in $H_2VO_4^-$ and HVO_4^{2-} species) and result in geochemical enrichment.

Figure 1 pH-Redox diagram for Vanadium

282 THE SOIL CHEMISTRY OF HAZARDOUS MATERIALS

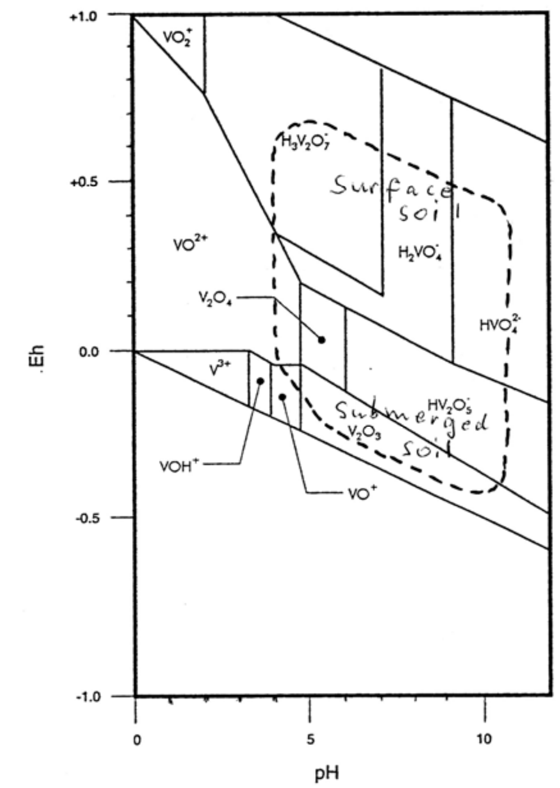

Figure 3.44 Vanadium, Eh-pH diagram for a V-H_2O system, where V activity is 10^{-4}. Constructed from data presented in references 16, 17, and 18

Vanadate (V^{5+} ion in $H_2VO_4^-$ and HVO_4^{2-} species) is stable under oxidising conditions and vanadyl (V^{4+}) is associated with reducing conditions as VO^{2+} and $VO(OH)^+$ species.

Vanadium toxicity is extremely rare, except when soluble forms of vanadium are applied to the soil or nutrient solutions. Most literature references to vanadium toxicity refer to fish and other aquatic organisms after vanadium has been added to the water.

Examples of phytotoxic effects are very rare, except where vanadium has been released into the environment from man-made sources, e.g. leaf necrosis due to V-rich ash from an oil-burning plant. Vanadium toxicity of dairy cows has been reported where cows were grazing down wind of a vanadium alloy processing facility in South Africa (Gummow, et al.)[7], in which case the V concentration of the topsoil was much higher than of the subsoil, and that of unwashed grass very much higher than of washed grass.

Table 1 is based on our own studies of potential vanadium toxicity of pasture grasses and toxicity to sheep near a cement kiln south of Geelong. We found that there was no evidence of any toxicity of either the grass or the sheep, but the sheep appeared to suffer from copper deficiency.

What is very evident is the association of vanadium with the subsoil, which applies also to arsenic, to the extent it is present in the environment, and to chromium. The subsoil samples were taken in the upper part of the B horizon, where grass roots do penetrate. Nevertheless, the content of vanadium is always less than 10 mg/kg, and shows no relationship to levels of vanadium in the topsoil and subsoil.

[7] Gummow, B., Bastianello, S.S., Botha, C.J., Smith, H.J.C., Basson, A.J. and Wells, B. (1994). Vanadium air pollution: a cause of malabsorption and immunosuppression in cattle. Onderstepoort J. Veterinary Res., Vol. 61: p.303-316.

In this case also, vanadium levels in the topsoil are much less than those in the subsoil, so that it may be concluded the vanadium is indigenous.

Acute vanadium toxicity data exist only for a few plant and invertebrate species and have been obtained by adding vanadium penta-oxide (V_2O_5) to an artificial soil[8] which had a pH of 4.3 (extremely acid), 5.6% organic matter and 22 % clay. In these examples, lettuce seeds (*Lactuca sativa*) and radish seeds (*Raphanus sativus*) and an earthworm species (mature *Eisenia fetida*) were subjected to added vanadium. The criterion was 50% emergence/survival, which was associated with a soil test results of, respectively, 249, 569 and 366 mg/kg. Similar data were obtained by measuring the impact on soil microbiological life through the inhibition of the soil's respiration rate, its nitrogen mineralisation rate and its nitrification rate for different soil textures after adding various soluble vanadium compounds.

The water solubility of the vanadium salts used in these tests are given as shown below, but sometimes more than one value is provided[9]:

Table 2 Water solubility of various vanadium salts

Salt	Sw	unit	T °C	mg/L
$NaVO_3$	17.42	wt%	25	174200
$NaVO_3$	21	wt%	25	210000
Na_3VO_4	s H2O	-	-	-
NH_4VO_3	4.35	wt%	18	43500
$VOSO_4$	s H2O	-	-	-
V_2O_5	0.07	wt%	25	700

None of these tests have any meaning in terms of the vanadium that has been locked up in the soils at Somerville by geochemical processes taking place over millennia.

Similarly, determining Total Vanadium levels in soils provide no insight whatsoever in terms of environmental risk.

8 Van Vlaardingen, P.L.A., Posthumus, R., and Posthuma-Doodeman, C.J.A.M. (2005). Environmental risk limits for nine trace elements. RIVM Report 601501029, Bilthoven, The Netherlands.
9 RIVM Report (Op. cit.)

Table 1 Distribution of arsenic, chromium and vanadium in soils on basalt, limestone and associated pasture

`	DP1	DP1	DP1	DP4	DP4	DP4	DP2	DP2	DP2	DP3	DP3	DP3	UP1	UP1	UP1
	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Lime stone	Lime stone	Lime stone	Lime stone	Lime stone	Lime stone	Basalt	Basalt	Basalt
	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil
	291 *	292	293	300 *	301	320	294 *	295	296	297 *	298	299	302 *	303	304
	MA124 3	MA124 4	MA124 5	MA125 2	MA125 3	MA125 4	MA124 6	MA124 7	MA124 8	MA124 9	MA125 0	MA125 1	MA125 5	MA125 6	MA125 7
HEAVY METALS															
Antimony	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	<2	7.0	35	<2	8.8	28	<2	14	22	<2	12	22	<2	19	10
Barium	30	36	38	19	35	29	17	55	56	17	61	82	15	67	70
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	<5	36	100	15	32	44	<5	30	40	<5	29	33	<5	44	90
Cobalt	<5	<5	6.0	<5	<5	<5	<5	5.3	<5	<5	<5	<5	<5	5.5	11
Copper	<5	<5	6.1	<5	<5	<5	<5	5.2	<5	<5	<5	<5	<5	5.5	11
Lead	<5	6.7	16	<5	7.8	10	<5	8.1	11	<5	8.0	12	<5	5.4	<5
Manganese	10	46	18	9.0	140	58	30	50	31	14	74	44	8.8	100	180
Mercury	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1
Molybdenum	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel	<5	11	16	<5	11	7.3	<5	7.5	6.0	<5	8.3	6.9	<5	16	36
Boron	17	7.4	<5	19	6.6	<5	19	7.8	<5	22	6.0	<5	17	<5	<5
Selenium	<2	5.5	11	<2	5.1	6.8	<2	5.2	5.7	<2	5.0	5.8	<2	5.5	7.6
Tin	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Vanadium	<10	55	180	<10	51	130	<10	63	73	<10	55	83	<10	66	110
Zinc	16	21	21	15	25	15	14	22	19	14	24	19	17	24	27

Table 1 Continued

`	UP2	UP2	UP2	UP3	UP3	UP3	UP4	UP4	UP4	CP1	CP1	CP1	CP2	CP2	CP2
	Basalt	Basalt	Basalt	Lime stone	Lime stone	Lime stone	Lime stone	Lime stone	Lime stone	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil	Grass	Topsoil	Subsoil
	305 *	306	307	308 *	309	310	311 *	312	313	314 *	315	316	317 *	318	319
	MA1258	MA1259	MA1260	MA1261	MA1262	MA1263	MA1264	MA1265	MA1266	MA1267	MA1268	MA1269	MA1270	MA1271	MA1272
HEAVY METALS															
Antimony	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Arsenic	<2	3.4	4.4	<2	<2	8.6	<2	7.0	55	<2	7.8	6.6	<2	2.2	5.0
Barium	44	61	70	29	36	32	20	29	26	20	34	26	29	33	29
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	<5	50	79	<5	28	66	46	24	76	<5	61	57	<5	25	37
Cobalt	<5	7.2	9.0	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Copper	<5	11	11	<5	6.0	<5	<5	<5	<5	<5	11	<5	<5	<5	<5
Lead	<5	<5	<5	<5	<5	5.6	<5	5.5	13	<5	6.8	6.2	<5	5.3	5.9
Manganese	58	180	160	48	61	34	26	56	33	31	64	51	100	61	46
Mercury	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1	<0.1
Molybdenum	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Nickel	<5	19	26	<5	11	11	<5	6.6	6.9	<5	12	11	<5	8.0	8.1
Boron	28	<5	<5	15	11	<5	13	6.6	<5	18	<5	<5	22	7.2	<5
Selenium	<2	5.2	6.3	<2	2.6	5.2	<2	3.4	8.2	<2	5.1	5.0	<2	3.0	3.8
Tin	<10	12	13	<10	<10	<10	<10	<10	<10	<10	<10	12	<10	10	<10
Vanadium	<10	56	110	<10	22	110	<10	55	260	<10	120	130	<10	32	84
Zinc	25	21	24	17	17	17	16	18	21	14	20	18	19	17	17

4. SUITABLE ALTERNATIVE SOIL QUALITY CRITERIA FOR VANADIUM

Because vanadium in normal aerated soils will be in the penta-valent form, vanadate, which is an anion, it may be possible to develop a criterion for bio-availability by using similar extraction techniques as are used to estimate plant-available phosphate, such as bi-carbonate-extractable P_2O_5, Olsen-extractable P_2O_5, Lactate-extractable P_2O_5, or fluoride-extractable P_2O_5.[10] The phosphate anion shares some of its chemistry with vanadate in relation to adsorption on ferruginous material and organic matter.

All of these extractions have in common that they are mild extractions that are meant to simulate the freely available phosphate in the soil solution. In agricultural practice over very many years these tests have been correlated with plant responses to added phosphate or to yield depressions, when the tests indicated deficiencies. These methods attempt at minimizing the changes to the soil sample due to the extractant.

In the environmental risk assessment area, in my opinion, this level of understanding has not been reached. Instead one is labouring under the continued dominance of Total and TCLP Leachable test methods which may or may not be significant to observed environmental problems. These tests are normally slavishly carried out without simultaneous determination of (a) soil pH, (b) levels of iron, and (c) degree of oxidation or reduction of the soil, all of which can have a major influence on solubility and mobility of the contaminant. This is the result of the Regulator having an exclusive focus on the contaminant and being blind to what makes it a danger or renders it harmless, i.e. the geochemical process.

5. VANADIUM RISKS AT LOT 38, SOMERVILLE

The vanadium at Lot 38, Somerville, does not pose an environmental risk.

This is so because it is associated with ferruginous materials, both being indigenous to the soil, and both having accumulated in the subsoil over many millennia in spite of being in a moist climatic zone with net leaching.

The fact that the vanadium and the iron are still present is eloquent evidence of them not being mobile in terms of short-term biological effects. The short-term perspective is related to the life span of living organisms.

6. BEHAVIOUR AND ENVIRONMENTAL RISKS OF ARSENIC

Arsenic also has been known since the early 20th century to associate with iron in the soil and in marine sediments, and to accumulate where iron accumulates. Hence, in the final residue of prolonged alumino-silicate rock or soil weathering, bauxite (hydrate minerals of $Al(OH)_3$ such as gibbsite, diaspore and boehmite), when these are rich in Fe, they also have become enriched in As[11]. This is perfect proof that the As in this combination is insoluble. Norrish reports that Fe-rich bauxites contained about 500 mg/kg of As.

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[10] Rayment, G.E. and Higginson, F.R., (1992). Australian Soil and Land Survey Handbook – Australian Laboratory Handbook of Soil and Water Chemical Methods. Inkata Press, Melbourne.
[11] Norrish, K. 1975. Op Cit.

This association has also been known in Australia for a long time, especially in the mining industry. There are numerous examples of ferruginous accumulations in soils and weathered rock strata that also have elevated As levels.

For example, the excavations for the new Museum in Melbourne, next to the Exhibition Building, penetrated into highly weathered Silurian mudstone and siltstone strata, where elevated arsenic was proved to be incorporated and occluded in ferruginous layers. The As could be liberated by a selective dissolution of the ferruginous fraction of these strata using a citrate-dithionite reagent, but could not be dissolved by the TCLP leaching test (See Figure 3). The deep weathering of these Silurian rocks dated back to the Tertiary and so the accumulation of the iron and As could be between 40 and 60 million years old. In that time these minerals have appear not to have moved.

Ferruginous gravels, “buckshot”, in the subsurface of very many Australian soils have similarly been formed by alternating periods of anaerobicity and aeration that cause Fe to precipitate around nuclei in the soil and form larger units of secondary iron oxides. They often have accumulated a range of other heavy metals that geochemically behave likewise. The shores of the Sugarloaf Reservoir have a beach of these ferruginous gravels that contain elevated arsenic and chromium in this case.

Figure 2 Ferruginous gravel from the Sugarloaf Reservoir.

Table 3 The top row in the Table represents total concentrations and the bottom row the TCLP concentrations. It can be seen there is no relationship between total and TCLP concentrations.

mg/kg (except Fe in %) and mg/L

As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Mo	Ni	Se	Sn	Zn
160	<0.5	150	8.5	18	19 %	42	78	<10	34	<2	<10	38
As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Mo	Ni	Se	Sn	Zn
< 0.02	< 0.05	< 0.05	< 0.05	< 0.05	0.38	< 0.05	0.13	< 0.5	< 0.05	< 0.02	< 0.5	0.63

Table 4 The arsenic – iron connection in weathered Silurian sedimentary rock at the Melbourne Museum site. C/D means citrate-dithionite selective dissolution.

Museum Excavation – Arsenic related to Iron Content of Rust-Coloured Strata

Depth *(m)* & Sample #	Banding	Total As *(mg/kg)*	Total Fe *(mg/kg)*	TCLP As *(mg/L)*	Total As after C/D *(mg/kg)*	As in C/D extr. *(mg/kg)* *(%)*	Fe in C/D extr. *(mg/kg)* *(%)*
9.8 (C)		4.0	20,000	<0.001	1.8	2.2 (55)	--- (28)
10.2 (C)		4.5	178,000	<0.001	3.6	0.9 (20)	--- (7.8)
10.5 (C)		5.0	24,000	<0.001	2.8	2.2 (44)	--- (24)
11.0 (C)		7.5	180,000	<0.001	4.5	3.0 (40)	(7.8)
2.0 (V)		13	20,000	<0.001	2.3	10.7 (82)	--- (41)
2.5 (V)		40.0	36,000	<0.001	24.0	16.0 (40)	--- (47)
4.9 (V)		<2	2,000	<0.001	<2	<0.1	--- (<0.1)
5.1 (V)		13.0	42,000	<0.001	6.1	6.9	--- (36)
7.0 (V)		7.0	124,000	<0.001	1.3	5.7 (81)	--- (25)
9.9 (V)		<2	680	<0.001	<2	<0.1	--- (<0.1)
10.0 (V)		<2	6800	<0.001	<2	<0.1	--- (74)
10.1 (V)		5.2	124,000	<0.001	0.7	4.5 (86)	--- (81)
10.2 (V)		11.0	114,000	<0.001	0.3	10.7 (97)	--- (23)
3.0 (BH85)		25.0	38,000	<0.001	15.0	10.0 (40)	--- (14)
3.2 (BH85)		8.5	55,000	<0.001	3.5	5.0 (59)	--- (11)
3.6 (BH85)		2.8	5,100	<0.001	0.3	2.5 (90)	--- (7.5)
6.0 (BH85)		4.0	25,000	<0.001	1.2	2.8 (70)	--- (30)

Notes: C = Coffey Partners core samples; V = van de Graaff pit face samples; BH85 = CMPS&F core samples

Table 4 illustrates that a high Fe content does not necessarily result in a high As content, but high As levels do follow high Fe levels. It is also suggestive that with the enormously high Fe concentration a single treatment with citrate-dithionite was not sufficient to dissolve all ferruginous matter. Unfortunately this extraction is not a routine of most or all environmental laboratories and lack of time for further research made it impossible to subject the samples to the test again.

Norrish also reports that detailed analyses of soil clays carried out in the CSIRO laboratory in Adelaide showed the Fe oxides, especially goethite (FeOOH) were extremely fine-grained, generally smaller than 0.02 μm, and therefore had an enormous specific surface area, making them potentially more active in adsorbing arsenic.

Table 1 also suggests that regardless of the arsenic levels in the soil, the plant, in this case pasture grasses, do not take up this element to a concentration that exceeds the sensitivity of the analytical method, 2 mg/kg.

7. ARSENIC RISKS AT LOT 38, SOMERVILLE

The arsenic at Lot 38, Somerville, does not pose an environmental risk.

This is so because it is associated with ferruginous materials, both being indigenous to the soil, and both having accumulated in the subsoil over many millennia in spite of being in a moist climatic zone with net leaching.

The fact that the arsenic and the iron are still present is eloquent evidence of them not being mobile in terms of short-term biological effects. The short-term perspective is related to the life span of living organisms.

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