



BlueSphere
ENVIRONMENTAL

**Tonsley VSCAP Investigations:
Further Groundwater and Soil Vapour Investigations
November 2017 to April 2018**

**Tonsley Innovation District
Former MMAL Site, Tonsley, SA**

Prepared for:

Renewal SA

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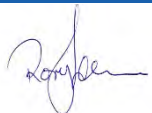


Tonsley VSCAP Investigations: Further Groundwater and Soil Vapour Investigations November 2017 to April 2018

Tonsley Innovation District Former MMAL Site, Tonsley, SA

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Executive Summary

Background

The Urban Renewal Authority trading as Renewal SA (Renewal SA) has entered into a Voluntary Site Contamination Assessment Proposal (VSCAP) with the EPA, dated 21 May 2015, for the Tonsley Development being undertaken within the former Mitsubishi Motors Australia Limited (MMAL) site.

The VSCAP establishes a framework for Site Contamination Assessment of volatile chlorinated hydrocarbons (VCH), petroleum hydrocarbons and other chemicals associated with vehicle manufacture, in groundwater for the MMAL site. The VSCAP identifies two areas within the MMAL site, referred to as EPA Designated Source Areas 3 and 4, which form the focus of the VSCAP investigations. It also requires consideration of the surrounding areas including parts of Clovelly Park (now Tonsley) and Mitchell Park. As part of the requirements of the VSCAP process, Renewal SA has engaged Mr Anthony Lane of SLR Consulting (formerly of Cardno) to conduct a restricted scope Site Contamination Audit (SCA) of EPA Designated Source Areas 3 and 4.

On 27 February 2017 the Auditor provided Interim Audit Advice (IAA) to the EPA which identified seven data gaps that required further investigation work. Subsequently, an additional data gap (Data Gap 8) was identified following discussions with the EPA.

BlueSphere Environmental Pty Ltd (BlueSphere) has been engaged by Renewal SA as a suitably qualified site contamination consultant to undertake site assessment work to address these data gaps. This work has been conducted via two separate programs of work. The first, referred to as the Further Groundwater and Soil Vapour Investigations, is described in this factual report. A second concurrent program referred to as the Source Investigation is described in a separate factual report.

Data from this report and the accompanying Source Investigation report will subsequently be used to inform the development of an updated Conceptual Site Model (CSM) for the MMAL site and surrounding areas, and an updated Human Health and Environmental Risk Assessment.

Investigation Area

The investigation area comprised:

- The former MMAL site, with the exception of the Residential Audit Area.
- The portion of Mitchell Park and Marion lying to the west of the former MMAL site bounded by the Tonsley rail corridor to the east; Sturt Road to the south, the Sturt River and the Noarlunga railway corridor to the west (with the addition of a small area of park between the south-western end of Minchinbury Avenue and the Sturt River); and Avalon Road and Hamilton Secondary College to the north.
- The portion of the suburb of Tonsley (previously known as Clovelly Park) to the south of the former MMAL site including the former R&C site and the area known as the Relocation Area. This area is bounded by the former MMAL site to the north and west, Ash Avenue to the south; and the Monroe site to the east.

For the purposes of this report the designation “on-site” refers to locations within the MMAL site and “off-site” refers to locations outside the boundary of the MMAL site, including the Monroe site, the former R&C site, and the surrounding suburbs.

Objectives

The overall objectives of this investigation are to assist in meeting Objectives 1 to 4 of the VSCAP. The specific objectives in relation to addressing the data gaps listed in the IAA are to:

- Obtain additional monitoring data from the on-site groundwater monitoring wells to provide greater confidence that the nature and extent of the VCH plume on, and immediately up hydraulic gradient of, EPA Designated Source Areas 3 and 4 is well characterised.
- Obtain additional monitoring data from the off-site groundwater monitoring wells (west and south of MMAL site) to provide greater confidence that the nature and extent of the off-site VCH plume has been adequately characterised, and to assess the stability of the dissolved VCH contamination identified.
- Obtain additional soil vapour data from within EPA Designated Source Areas 3 and 4 to assist in establishing whether there is a contamination source in the vadose zone, and to provide greater confidence that the soil vapour conditions in these areas are adequately characterised.
- Obtain additional monitoring data from the off-site soil vapour monitoring bores (west and south of MMAL site) to provide greater confidence that the nature and extent of the off-site VCH soil vapour impacts have been adequately characterised, and to assess any seasonal variations in the off-site soil vapour conditions.
- Obtain more data to improve the understanding the highly variable lithology encountered in the upper Quaternary aquifer.

Scope of Work

The key components of the scope of work described in this report are:

- Gauging the standing water level of 53 on-site groundwater monitoring wells within the former MMAL site and 56 off-site wells to the west and south of the MMAL site.
- A first round of sampling of 31 on-site and 41 off-site groundwater monitoring wells and analysis for volatile chlorinated hydrocarbons and total petroleum hydrocarbons.
- A second round of sampling of 18 on-site and 17 off-site groundwater monitoring wells where the groundwater contaminant concentrations had not been adequately characterised following the first round of sampling.
- Installation of 5 sets of on-site, multi-level soil vapour bores within the Audit areas
- A first round of sampling of 28 on-site and 23 off-site soil vapour monitoring bores and analysis for VCH and total petroleum hydrocarbons.
- A second round of sampling of 25 on-site and 22 off-site soil vapour monitoring bores where the soil vapour contaminant concentrations had not been adequately characterised following the first round of sampling.
- Geophysical logging of 21 existing off-site and 2 existing on-site groundwater monitoring wells.

Conclusions

The following key conclusions are drawn from this investigation:

- The groundwater contours inferred from the groundwater gauging round conducted in November/December 2017 are generally consistent with those obtained from previous gauging rounds and support the previous findings that the groundwater flow direction across the MMAL site is broadly in a west to north-westerly direction, swinging more to the north-west down-gradient of the MMAL site in Mitchell Park and Marion.
- On-site VCH groundwater concentration data obtained in January and April 2018 showed a high degree of consistency with data from previous recent monitoring events. It is therefore considered that the nature and extent of the VCH plume beneath, and immediately up hydraulic gradient of, EPA Designated Source Areas 3 and 4 is well characterised.

- The extent of the off-site groundwater VCH plume within the uppermost Quaternary aquifer in Mitchell Park and Marion has been well delineated to the 5 µg/L level of detection. The concentrations of VCH in groundwater have shown a high degree of stability over the monitoring period from 2014 to 2018, suggesting that the nature and extent of the off-site VCH plume has been adequately characterised, and that the plume has been stable over the monitoring period.
- Two rounds of sampling data from the three sets of three on-site soil vapour bores installed in EPA Designated Source Area 4 indicate that the concentrations of VCH in shallow soil vapour at a depth of 2 m are low (<20 µg/m³) in EPA Designated Source Area 4.
- On-site soil vapour data collected in November 2017 and March 2018 from existing soil vapour bores and two newly installed sets of bores within EPA Designated Source Area 3 provided further evidence of very high soil vapour VCH concentrations along the southern boundary of EPA Designated Source Area 3 (adjoining the Relocation Area). Much lower soil vapour VCH concentrations were reported in the central and northern portions of EPA Designated Source Area 3.
- Off-site soil vapour data collected in November 2017 and March 2018 showed a high degree of consistency with previous data collected between 2014 and 2016, suggesting that the VCH concentrations in shallow soil vapour within Mitchell Park are broadly stable and are well characterised at the existing soil vapour bores. Some seasonal variation in VCH soil vapour concentrations was noted.
- Geophysical logging data indicated that the lithology of the upper Quaternary aquifer comprises predominantly low permeability clay and sandy clay, interspersed with irregularly distributed, laterally discontinuous, higher permeability gravelly / sandy layers. The thickness, permeability and frequency of these higher permeability bands shows considerable spatial variability across the investigation area, which is likely to result in substantial differences in hydraulic conductivity in different portions of the investigation area. The following spatial patterns were evident:
 - A zone of relatively high clay content in saturated zone soils (indicating low permeability) is present in the vicinity of the Relocation Area, the former R&C site and the south-west corner of the MMAL site;
 - Slightly lower clay contents in saturated zone soils were seen to the north of Section 14 in the vicinity of the current TAFE building; and
 - The clay content of the saturated zone soils is substantially lower in the western portion of Mitchell Park and in Marion, indicating that a more sandy (higher permeability) lithology is dominant in this area.

In general, it was concluded that the data obtained successfully addressed the specific objectives of the investigation by providing the specified additional data required to address the targeted IAA data gaps.

1 Introduction

1.1 Appointment

BlueSphere Environmental Pty Ltd (BlueSphere) has been engaged by Renewal SA as the suitably qualified and experienced site contamination consultant to undertake the Site Contamination Assessment tasks relating to the former Mitsubishi Motors Australia Limited (MMAL) Tonsley Park site (hereafter referred to as the MMAL site), located in Tonsley, South Australia. The location of the MMAL site is shown on **Figure F1**.

1.2 Definition of the Investigation Area

Assessment investigations undertaken as part of the scope of works described in this report have been limited to the following areas:

- The former MMAL site, with the exception of the Residential Audit Area.
- The portion of Mitchell Park and Marion lying to the west of the former MMAL site bounded by:
 - The Tonsley rail corridor to the east;
 - Sturt Road to the south;
 - The Sturt River and the Noarlunga railway corridor to the west (with the addition of a small area of park between the south-western end of Minchinbury Avenue and the Sturt River); and
 - Avalon Road and Hamilton Secondary College to the north.
- The portion of the suburb of Tonsley (previously known as Clovelly Park) to the south of the former MMAL site including the former R&C site and the area known as the Relocation Area. This area is bounded by:
 - The former MMAL site to the north and west;
 - Ash Avenue to the south; and
 - The Monroe site to the east.

The area is hereafter referred to as “the investigation area” and is shown on **Figure F2**.

For the purposes of this report the designation “on-site” refers to locations within the MMAL site. The designation “off-site” refers to locations outside the boundary of the MMAL site, including the Monroe site, the former R&C site, and the surrounding suburbs (Tonsley, Mitchell Park and Marion).

1.3 Definitions of Geographic Descriptor Terms

Due to the complex nature and land use history of the Tonsley precinct and its surrounds, it has been necessary for the purposes of this report to adopt a number of terms to describe various sections of the precinct. Each of the geographic descriptors used in this report are defined in **Table 1** below and shown on **Figure F2**, for clarity and future reference.

Table 1 Definitions of Geographic Descriptor Terms used in the Report

Descriptor	Definition
Investigation Area	The area within which intrusive investigations have been conducted as part of this investigation as defined in Section 1.2 above. It is noted that this does not include the portion of the former MMAL site that is known as the Residential Audit area.
on-site and off-site	“on-site” refers to locations within the MMAL site. The designation “off-site” refers to locations outside the boundary of the MMAL site, including the Monroe site, the former R&C site, and the surrounding suburbs of Tonsley, Mitchell Park and Marion.
MMAL site	The area previously occupied by MMAL for motor vehicle manufacturing and now owned by Renewal SA.
EPA Designated Source Areas 3 and 4	The two areas in the south west and central west parts of the MMAL site that have been designated as “source areas” by the EPA within the VSCAP.
Audit area	The two non-contiguous areas, comprising EPA Designated Source Areas 3 and 4, that form the area currently under a Site Contamination Audit (SCA) by Anthony Lane of SLR.
Residential Audit area	The north western part of the MMAL site that has recently had a SCA Report (SCAR) completed by Adrian Webber of MUD Environmental for residential development.
TAFE Audit area	The south central section of the MMAL site that is now occupied by the TAFE building that has been audited by Phillip Hitchcock of Australian Environmental Auditors.
Monroe site	The Monroe Australia Pty Ltd facility immediately south east of the MMAL site that is currently under SCA by Steven Kirsanovs of Kirsas Environmental.
Mitchell Park	For the purposes of this report, the term Mitchell Park is used to describe the portion of the investigation area that lies to the west and south west of the MMAL site and to the east of Marion Road comprising the suburb defined as Mitchell Park.
Marion	For the purposes of this report, the term Marion is used to describe the portion of the investigation area that lies to the west of Mitchell Park. i.e. to the west of Marion Road comprising the suburb defined as Marion.
Tonsley (south)	For the purposes of this report, the term Tonsley (south) is used to describe the portion of the investigation area that lies immediately south of the MMAL site, to the east of the railway corridor. This area was previously part of the suburb of Clovelly Park but has now been gazetted as part of the new suburb of Tonsley.
Relocation Area	The portion of the suburb of Tonsley (south), including the former R&C site, Chestnut Court and the northern side of Ash Avenue, from which residents have been relocated due to potential health risks from TCE vapours.

1.4 General Background Information

During 2008 the Environment Protection Authority South Australia (EPA) was notified of volatile chlorinated hydrocarbon (VCH) contamination in groundwater beneath the southern portion of the MMAL site. The MMAL site was then owned by MMAL and had been used for automotive manufacturing for 40 years. Following the closure of the MMAL operations, Land Management Corporation (now Renewal SA) purchased the MMAL site on 25 January 2010 for the purposes of urban renewal as a mixed-use commercial and education centre with medium density residential housing and open spaces.

Since the early 1990s, a large volume of assessment work has been completed at the MMAL site and at surrounding industrial and residential properties. There is a total of approximately 150 reports for various environmental assessments. These include multi-phase intrusive assessments of soil, soil gas, indoor air monitoring and groundwater, human health and environmental risk assessment, groundwater monitoring events, desk top assessment, removal of underground storage tanks (USTs) and remediation of shallow soils associated with the USTs.

Extensive environmental investigations conducted to date indicate that widespread contamination of groundwater by TCE and PCE and their degradation products DCE and VC has occurred across the MMAL site and adjacent areas. These contaminants are hereafter collectively referred to as volatile chlorinated hydrocarbons (VCH). It is likely that this VCH contamination has resulted, at least in part, from spillage and losses of chlorinated hydrocarbon solvent material within the Monroe site immediately east of the MMAL site. Groundwater data suggests VCH contamination from these losses has subsequently migrated in groundwater off the Monroe site in a generally western direction beneath the MMAL site and surrounding residential areas.

VCH contamination in groundwater (primarily TCE) extends to the west of the MMAL site for a distance of approximately 1.6 kilometres, with the plume aligned in a north-westerly direction. The off-site plume is largely located within the suburb of Mitchell Park; however, the down-gradient tip of the plume extends into the neighbouring suburb of Marion.

Soil vapour impacts, most likely associated with the groundwater VCH plume, have been identified in the area to the south and west of the former MMAL site. An unacceptable level of risk from intrusion of VCH vapour has been identified for some residential buildings located to the south of the MMAL site. Consequently, the EPA established a residential Relocation Area in the Tonsley neighbourhood to mitigate potential risks. Due to the impacts on adjacent off-site properties, community consultation has been undertaken by the EPA and other stakeholders.

Based on the historical assessments, the source of the VCH contamination is likely to be comingled groundwater impacts from industrial activities in the vicinity of the MMAL site. Potential source sites include the Monroe Australia Pty Ltd site (the Monroe site), the former Reckitt and Colman (R&C) site, and the MMAL site (see **Figure F2**).

Petroleum hydrocarbon impacted groundwater has also been reported at a number of locations across the MMAL site, which may also have had the potential to migrate off-site and impact off-site receptors.

It is noted that in conducting the initial post-closure investigations of the MMAL site on behalf of MMAL in 2008, Parsons Brinckerhoff (PB, 2008a) divided the MMAL site into 19 sections based on the historic manufacturing activities conducted within each section. These section designations have been widely used to describe the MMAL site in the numerous investigation reports prepared for the site since 2008. A figure showing the division of the MMAL site into the 19 sections is provided as **Figure F3** for reference.

1.5 VSCAP

The Urban Renewal Authority trading as Renewal SA (Renewal SA) has entered into a Voluntary Site Contamination Assessment Proposal (VSCAP) with the EPA, dated 21 May 2015, for the Tonsley Development being undertaken within the MMAL site. A copy of the VSCAP is provided as **Appendix A**.

The VSCAP establishes a framework for Site Contamination Assessment of VCHs, petroleum hydrocarbons and other chemicals associated with vehicle manufacture, in groundwater for the MMAL site. It also requires consideration of the broader surrounding areas including parts of Tonsley (formerly Clovelly Park) and Mitchell Park. The VSCAP identified two areas within the MMAL site, referred to as EPA Designated Source Area 3 and EPA Designated Source Area 4, which form the focus of these investigations. The designated source areas and the broader investigation area are shown on **Figure F2**. The objectives of the VSCAP, as set out in Section 4.1 of the VSCAP are as follows:

- 1) Determine the nature and extent of any Groundwater Contamination within the MMAL site from EPA Designated Source Area 3 to facilitate the development of a subsequent Voluntary Site Remediation Proposal (VSRP), if required as a result of the proposed Site Contamination Assessment (**Objective 1**).
- 2) Determine the nature and extent of any Groundwater Contamination within the MMAL site from EPA Designated Source Area 4 to facilitate the development of a subsequent Voluntary Site Remediation Proposal (VSRP), if required as a result of the proposed site Contamination Assessment (**Objective 2**).
- 3) To assess the risks from any Groundwater Contamination in the groundwater migrating off the western boundary of the MMAL site from EPA Designated Source Area 3 (**Objective 3**).
- 4) To assess the risks from any Groundwater Contamination in the groundwater migrating off the western boundary of the MMAL site from EPA Designated Source Area 4 (**Objective 4**).
- 5) To assess the existence of (and as may be required, assess the nature and extent of) Groundwater Contamination originating from the Residential Audit Area and migrating to the area north of Alawoona Ave and to the west of the site, being portion of the Community Engagement Area (**Objective 5**).
- 6) To assess the existence of (and as may be required, assess the nature and extent of) Groundwater Contamination originating from the Residential Audit Area and migrating to the area north of the northern boundary of the site, being portion of the Community Engagement Area (**Objective 6**).
- 7) The development and application of a Community and Stakeholder Engagement Plan in respect of the Community Engagement Area (**Objective 7**).

The primary contaminants of potential concern (CoPC) identified in the VSCAP are trichloroethene and tetrachloroethene and their biodegradation daughter products. This group of compounds is specifically defined in the VSCAP under the generic term Volatile Chlorinated Hydrocarbons (VCH) and comprises the following compounds:

- tetrachloroethene (PCE);
- trichloroethene (TCE);
- 1,1-dichloroethene (1,1-DCE);
- cis-1,2-dichloroethene (cis-1,2-DCE);
- trans-1,2-dichloroethene (trans-1,2-DCE); and
- Vinyl chloride (VC).

The VSCAP also specifies that the investigations must consider petroleum hydrocarbons and all other chemical substances associated with the potentially contaminating activity of motor vehicle manufacture as defined in the *Environmental Protection Regulations (2009)*. While this VSCAP statement appears to be quite broad, the CoPC have been interpreted to include the following chemicals on the basis of historical environmental assessment reports:

- Petroleum hydrocarbons: TRH C₆-C₄₀, benzene, ethylbenzene, toluene, xylene isomers m, o and p, naphthalene and methyl tert-butyl ether (MTBE);
- Hexavalent chromium;

- Other halogenated solvents: including 1,1,2,2-tetrachloroethane, 1,1,1-trichloroethane and a full suite of halogenated solvents at select areas;
- Other monoaromatic hydrocarbons: including 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, styrene at select areas;
- Non chlorinated solvents: including methyl ethyl ketone, 2-hexanone, 4-methyl-2-pentanone, carbon disulfide and vinyl acetate;
- Other metals: arsenic, total chromium (III and VI), copper, lead, nickel at select areas; and
- Cyanide.

Initial investigations conducted by BlueSphere in 2015 and 2016 (BlueSphere, 2016a, 2016b, 2016c) assessed the range of CoPC listed above and confirmed that the primary CoPC on the MMAL site were VCH and petroleum hydrocarbons. The further groundwater and soil vapour investigations described in this report have therefore focussed on these primary CoPC.

Vertically, the VSCAP is confined to the uppermost Quaternary (water table) aquifer and soil vapour within the unsaturated zone above the water table.

1.6 Site Contamination Audit

As part of the requirements of the VSCAP process, Renewal SA has engaged Mr Anthony Lane (the Auditor) of SLR Consulting Australia (SLR) (formerly of Cardno Victoria Pty Ltd (Cardno)) to conduct a Site Contamination Audit (SCA) of two non-contiguous areas identified as EPA Designated Source Areas 3 and 4. The EPA reference number for the SCA is 61504.

The Audit is restricted to elements of the environment including soil vapour and water and specifically excludes elements of soil, sediments, air, organisms, ecosystems, human-made or modified structures or areas, and amenity values (e.g. odour, aesthetics). The Audit is restricted to chemical substances associated with motor vehicle manufacture including volatile chlorinated hydrocarbons (VCH), daughter products and petroleum hydrocarbons.

The following aspects and activities are excluded from the restricted scope Audit:

- Determination of suitability for sensitive or other land uses;
- Deep aquifers, below the water table aquifer e.g. deeper Quaternary and Tertiary aquifers. This audit is restricted to the assessment of the water table Quaternary aquifer from which volatile contaminants can be emitted into the vadose zone;
- Chemical substances not associated with the motor vehicle manufacture activities that may have been previously used at the MMAL site;
- Nature, extent and potential risk associated with soil-adsorbed impacts; and
- Community engagement and associated communication activities.

EPA Designated Source Area 3 lies in the south-western corner of the former MMAL site within the section of the site designated as Section 14 by PB during the initial post-closure investigations conducted in 2008. It covers an area of approximately 1.4 Ha. EPA Designated Source Area 4 lies to the north of Source Area 3 along the western boundary of the MMAL site and covers an area of approximately 2.2 Ha. It lies mainly within the section designated by PB as Section 19b, but also extends into parts of Section 17 and 18.

The audit areas are hereafter referred to as “EPA Designated Source Area 3” and “EPA Designated Source Area 4”. The extent of these areas is shown on **Figure F2**.

On 27 February 2017 the Auditor provided Interim Audit Advice (IAA) to the EPA (Cardno 2017). Section 4.5 of the IAA stated that, whilst the conceptual site model (CSM) is considered to be comprehensive and provides a sufficient basis for assessing and managing risks, seven data gaps were identified. Subsequent to the provision of the IAA, an additional data gap (Data Gap 8) was identified following discussions with the EPA. The eight identified data gaps are:

- 1) The association between potential off-site sources of contamination at the R&C site and contamination pathway in Relocation Area with the impacts in EPA Designated Source Area 3 (and MMAL site) are not fully understood.
- 2) As currently a majority of the soil vapour bores are located near the boundary of EPA Designated Source Areas 3 and 4, more soil vapour data from within Areas 3 and 4 would assist in establishing whether there is a contamination source in the vadose zone. It is noted that for some soil vapour bores, there has been only one round of monitoring completed.
- 3) Improve the understanding of the hydrogeology and contaminant plume. This would assist with gathering more data to improve the certainty in nature and extent of the groundwater contamination as well as understanding the highly variable lithology encountered in the upper Quaternary aquifer. Specifically, additional assessment of aquifer zone architecture and hydraulic properties to address the apparent conundrum of plume length being vastly longer than the Conceptual Hydrogeological Model estimates of seepage velocity indicate.
- 4) As the soil investigation to date has been limited to 2 m below surface, the potential for sources of contamination in EPA Designated Source Area 3 deeper than 2 m has not been fully assessed.
- 5) Soil intrusive works (such as test pits or trenches) have not been conducted in EPA Designated Source 4 and therefore, there is limited information available about whether there are potential sources present.
- 6) The monitoring results from the off-site groundwater monitoring bores (west of MMAL site) are limited and may not be representative as some of the off-site bores have only been sampled on one occasion only. Further sampling would be required to verify the stability of the dissolved TCE contamination identified.
- 7) On 23 February 2017, SA EPA wrote to Renewal SA to seek clarification about the potential for the Oaklands Wetlands and associated Managed Aquifer Recharge (MAR) system to be a potential receptor of impact from the shallow contaminated groundwater in the water table Quaternary aquifer. The initial advice from BlueSphere (email correspondence 24 February 2017, appended to the IAA) indicates that there is a negligible risk of such impact due to the lack of potential pathway and the separation distance between the plume and the wetland. This interpretation has been documented in an addendum to the CSM, but no appropriate site plans were provided to show the location of the wetlands.
- 8) Uncertainty in the Human Health and Environmental Risk Assessment (HERA) (BlueSphere, 2017a) with regard to current or future soil vapour intrusion risks at locations where modelled TCE vapour concentrations in basements exceeded investigation and intervention levels.

Two further scopes of work have been conducted to address these gaps. The first investigation titled "Further Groundwater and Soil Vapour Investigations" is described in this report and is designed to primarily address Data Gaps 2, 3, 6 and 8, although data obtained from this scope of work are likely to provide supporting evidence with regard to Data Gap 1.

The second investigation titled "Source Investigation" is described in a separate report and is primarily designed to address data gaps Data Gaps 1, 3, 4, and 5.

Data Gap 7 is to be addressed in a separate document and will include preparation of additional figures based on currently available data. Aspects of Data Gap 8 relating to the presence of basements is to be addressed in a separate document and will include a survey of the potentially affected properties.

1.7 Other Site Contamination Audits

Three other areas within the former MMAL site and the surrounding area are currently under audit or have previously been audited. These are:

- The north western portion of the MMAL site, known as the Residential Audit area, which has been audited by Mr Adrian Webber of MUD Environmental (SCAR submitted, EPA reference 61286-001A);

- A small portion in the central northern part of the MMAL site, known as Lot 331, which has been audited by Mr Phillip Hitchcock of Australian Environmental Auditors Pty Ltd (SCAR submitted, EPA reference 61778);
- The central area of the MMAL site, known as the TAFE Audit area, which has been audited by Mr Phillip Hitchcock of Australian Environmental Auditors Pty Ltd (SCAR submitted, EPA reference 60513); and
- The Monroe site located to the west and south of the MMAL site which is currently being audited by Mr Steven Kirsanovs of Kirs Environmental Pty Ltd (EPA Reference 60107).

The area covered by each of these audits is shown on **Figure F2**.

1.8 Objectives

The overall objectives of this investigation, in relation to the VSCAP (**Section 1.5**), are:

- to assist in meeting the requirements of VSCAP Objectives 1 and 2; and
- to obtain information necessary to facilitate the subsequent fulfilment of VSCAP Objectives 3 and 4.

Specific objectives in relation to the data gaps listed in the IAA (Cardno, 2017) are:

- Obtain additional monitoring data from the on-site groundwater monitoring wells to provide greater confidence that the nature and extent of the VCH plume on, and immediately up hydraulic gradient of, EPA Designated Source Areas 3 and 4 is well characterised (**Data Gaps 3 and 1**).
- Obtain additional monitoring data from the off-site groundwater monitoring wells (west and south of MMAL site) to provide greater confidence that the nature and extent of the off-site VCH plume has been adequately characterised, and to assess the stability of the dissolved VCH contamination identified (**Data Gap 6**).
- Obtain additional soil vapour data from within EPA Designated Source Areas 3 and 4 to assist in establishing whether there is a contamination source in the vadose zone, and to provide greater confidence that the soil vapour conditions in these areas are adequately characterised (**Data Gap 2**).
- Obtain additional monitoring data from the off-site soil vapour monitoring bores (west and south of MMAL site) to provide greater confidence that the nature and extent of the off-site VCH soil vapour impacts have been adequately characterised, and to assess any seasonal variations in the off-site soil vapour conditions. This information is to be used to refine the uncertainties with regard to current or future soil vapour intrusion risks identified in the Human Health and Environmental Risk Assessment (HERA) (BlueSphere, 2017a) (**Data Gap 8**).
- Obtain more data to improve the understanding the highly variable lithology encountered in the upper Quaternary aquifer. This includes additional assessment of aquifer zone architecture and hydraulic properties to address the apparent conundrum of plume length being vastly longer than the Conceptual Hydrogeological Model estimates of seepage velocity indicate (**Data Gap 3**).

1.9 Nature of this Report

This report is intended as a factual report describing the scope of investigation works conducted within the investigation area (as defined in **Section 1.2**) from November 2017 to April 2018. It is intended to supplement previous reports relating to the Tonsley VSCAP prepared in 2016 and 2017 (BlueSphere, 2016a, 2016b, 2016c, 2017a, 2017b). The scope of work is as described in the Tonsley VSCAP Investigations: Further Groundwater and Soil Vapour Investigations Sampling and Analysis Quality Plan (SAQP) dated 20 October 2017 (BlueSphere, 2017c) and subsequent updates and correspondence with the Auditor.

This report is not a Detailed Site Investigation (DSI) report as defined by the National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended 2013) hereafter referred to as ASC NEPM. It is presented as a factual description of the works undertaken and presents the data generated with limited interpretation. Interpretation of the data is limited to Tier 1 assessment against published assessment criteria adopted as appropriate.

Detailed technical interpretation of data with regard to the nature and extent of contamination, fate and transport of contamination, and the potential risks to human health and the environment is not included in this report. This will subsequently be undertaken as part of future updates of the Conceptual Site Model and Human Health and Environmental Risk Assessment reports.

2 Previous Investigations

2.1 Summary

Numerous environmental investigations have been conducted on the MMAL site and the broader investigation area since approximately 1995. These reports have been commissioned by a number of different entities and cover the various sections of the MMAL site, the Monroe site to the south east of the MMAL site, the residential area to the south of the MMAL site in Tonsley (formerly Clovelly Park), and the residential area to the west of the MMAL site in Mitchell Park and Marion.

The VSCAP refers to a total of approximately 132 historical reports, being:

- Approximately 59 reports produced for MMAL;
- Approximately 12 reports produced for Monroe Pty Ltd;
- Approximately 58 reports produced for Renewal SA;
- Two reports produced for SA Housing Trust; and
- One report produced for SA EPA.

At the time of preparation of Progress Factual Report No. 1 (BlueSphere, 2016), the following reports were received from Renewal SA and reviewed by BlueSphere:

- 64 reports produced for MMAL;
- 19 reports produced for Monroe Pty Ltd;
- 46 reports produced for Renewal SA;
- Two reports produced for SA Housing Trust; and
- Two reports produced for SA EPA.

A list of these reports is provided in the Progress Factual Report No.1 and summaries of each report are included as Appendix B of the Progress Factual Report No.1 (BlueSphere, 2016a).

Since these reviews were prepared, BlueSphere has conducted an extensive groundwater monitoring well installation and sampling program to the west of the MMAL site within the suburbs of Mitchell Park and Marion, for the purpose of delineating the off-site VCH groundwater plume. This work is described in the following reports:

- Tonsley VSCAP Investigations: Mitchell Park Delineation Drilling June 2016. BlueSphere Environmental. 22 July 2016 (BlueSphere, 2016b); and
- Tonsley VSCAP Investigations: Stage 2 Delineation Drilling Mitchell Park and Marion August/September 2016. BlueSphere Environmental. 17 November 2016 (BlueSphere, 2016c).

The results of this work, along with the Progress Factual Report No 1 and the previous investigations, were considered in developing the Human Health and Environmental Risk Assessment for off-site receptors to the west of the MMAL site, and the Conceptual Site Model (CSM). These are described in the following reports:

- Tonsley VSCAP Investigation: Human Health and Environmental Risk Assessment. Tonsley Development, Former MMAL Site, Clovelly Park, SA. 17 January 2017 (BlueSphere, 2017a); and
- Conceptual Site Model (CSM): Tonsley VSCAP Investigation – Revision 3. Tonsley Development, Former MMAL Site, Clovelly Park, SA. BlueSphere Environmental 24 February 2017 (BlueSphere, 2017b).

The Residential Audit area is located in the north-western corner of the MMAL site (refer to **Figure F2**). Since the completion of the CSM (Revision 03) (BlueSphere 2017b), the Detailed Site

Investigation and subsequent Site Contamination Audit Report for the Residential Audit site have been completed. The Residential Audit Area data is of limited direct relevance to this investigation. Further details regarding the Residential Audit area can be obtained from the following reports:

- Detailed Site Investigation – Tonsley SANZ. Suburban Activity Node Zone – Tonsley. Greencap. October 2017. (Greencap, 2017); and
- Site Contamination Audit Report, Renewal SA, Residential Audit Area – Suburban Activity Node Zone, Portion of Former Mitsubishi Motors Australia Limited Site, Tonsley, Prepared by Adrian Webber (ME-007) (EPA Reference 61286), 7 December 2017. (Mud, 2017)

2.2 Previous Groundwater and Soil Vapour Monitoring Events

While the history of the environmental assessment of the MMAL site and surrounding areas is long and complex, the key groundwater and soil vapour investigations of direct relevance to this investigation have largely occurred as part of four distinct stages of assessment work. These are:

- An extensive program of groundwater well and soil vapour bore installation and groundwater and soil vapour sampling conducted by Parsons Brinckerhoff (PB) between 2008 and 2010 as part of the post-closure investigations of the MMAL site. This work was predominantly conducted within the MMAL site (i.e. on-site). It is described in the Phase 1 and Phase 2 ESA reports (PB, 2008a and 2008b) and the various section reports prepared by PB in 2009 and 2010, with the Section 14 report (PB, 2009) being the most relevant to this investigation.
- A program of installation and sampling of groundwater wells and soil vapour bores conducted by Fyfe on behalf of the SA EPA in 2014 and 2015. This work focussed mainly on off-site areas to the west and south of the MMAL site, although some investigations were conducted in Section 14 in the far south of the MMAL site. The work is described in the Clovelly Park / Mitchell Park Environmental Assessment Report (Fyfe, 2014) and the Mitchell Park Validation Assessment Works report (Fyfe, 2015).
- A groundwater and soil vapour monitoring event conducted by BlueSphere in 2015 across the investigation area. This program involved sampling of all active groundwater monitoring wells and soil vapour bores within the MMAL site (excluding the Residential Audit Area) and within Mitchell Park to the west of the MMAL site and Clovelly Park (since renamed as Tonsley) to the south of the MMAL site. This work is described in the Progress Factual Report No.1 (BlueSphere, 2016a).
- A program of groundwater well installation and sampling conducted within Mitchell Park and Marion to the west of the MMAL site by BlueSphere in 2016 for the purpose of delineating the off-site VCH groundwater plume. Some limited off-site soil vapour sampling was also conducted as part of this program. This work is described in the Mitchell Park Delineation Drilling report (BlueSphere, 2016b) and the Stage 2 Delineation Drilling Mitchell Park and Marion report (BlueSphere, 2016c).

Periodic groundwater and soil vapour investigation works have also been conducted within Section 14 and Tonsley to the south of the MMAL site by AECOM (formerly URS) on behalf of Monroe. This has included installation and sampling of groundwater wells and soil vapour bores. The results of these investigations are summarised in the Updated Environmental Health Risk Assessment report (AECOM, 2017).

2.3 Previous Geophysical Logging Investigations

A previous program of geophysical borehole logging was conducted by Borehole Wireline Pty Ltd, under the direction of BlueSphere, between 25 September 2015 and 29 September 2015. The geophysical borehole logging was conducted to provide detailed lithological information for the saturated zone soils within the upper Quaternary aquifer. The program comprised downhole gamma logging in 39 wells (23 on-site and 16 off-site wells) and induction (or conductivity) logging

at five of these wells. The logging program is described in the Progress Factual Report No.1 (BlueSphere, 2016). The logging report provided by Borehole Wireline is attached in **Appendix P**.

The gamma data showed that the logged wells typically had some regions of low clay content which is inferred to indicate higher sand and gravel content within the shallow Quaternary sediments. Some limited correlation of higher permeability zones was seen between adjacent wells that indicated a possible seaward-sloping clayey gravel or gravelly clay lens. However, the correlations were limited to wells within 100 m to 200 m of each other and no clear lateral correlation of possible higher permeability zones was seen across the on-site and off-site areas. This indicated that no clear laterally continuous zone (that may be considered to constitute a regional aquifer) was present within the investigation area.

The gamma data indicated that the uppermost Quaternary aquifer typically comprised a complex system of discontinuous clayey gravel and gravelly clay lenses with varying degrees of sand inclusions within the predominantly silty clay Quaternary sediments. These discontinuous possibly higher conductivity lenses were typically between 0.1 m and 0.5 m thick. Groundwater within these clayey gravel and gravelly clay lenses is likely to be semi-confined.

3 Site Characterisation

3.1 Site Identification

The details of the former MMAL site are summarised in **Table 2**. There have been significant and ongoing changes to the configurations of the Certificates of Titles (CoTs) on the MMAL site as part of the redevelopment. As of 3 May 2018, the MMAL site comprised 15 CoTs described in **Table 2** below.

Table 2 MMAL Site Details Summary

	Tonsley Development (based on VSCAP)
MMAL site area	Approximately 61 Ha
Site Owner	Various
Certificates of Title and Deposited Plan Allotment Nos.	CT 6201, Folio 875 (D115276, AL520) CT 6201, Folio 874 (D115276, AL518) CT 6149, Folio 30 (D94175, AL91) CT 6149, Folio 31 (D94175, AL92) CT 6149, Folio 32 (D94175, AL93) CT 6197 Folio 567 (D115503, A332) CT 6145, Folio 982 (D93980, AL101) CT 6145, Folio 984 (D93980, AL103) CT 6145, Folio 985 (D93980, AL104) CT 6145, Folio 986 (D93980, AL105) CT 6159, Folio 712 (D110117, A111) CT 6159, Folio 713 (D110117, A113) CT 6159, Folio 714 (D110117, A114) CT 6176 Folio 975 (D93980, AL102) CT 6157, Folio 497 (D95379, AL1011)
Local Government Authority	City of Marion
Planning Zone	Regional Activity
Street Address (Source: http://maps.sa.gov.au)	1284-1324 South Road, Tonsley, 5042.

The Audit areas directly relevant to this report (EPA Designated Source Areas 3 and 4) both lie within CT 6201 Folio 875 which is currently owned by Renewal SA. The Audit areas are shown on **Figure F2**.

As stated in **Section 1.2**, these investigations have also included sections of Mitchell Park, Marion and Tonsley adjoining the MMAL site. The extent of the investigation area is shown on **Figure F2**.

3.2 Site Description

The MMAL site, and the surrounding suburbs of Mitchell Park, Tonsley and Clovelly Park, lie at the south eastern margin of the Adelaide Plains, an area characterised by gently sloping topography, overlain by alluvial fans originating from the Southern Mount Lofty Ranges.

Locally, the investigation area is situated within unconsolidated sediments of the Adelaide Plains, and may possibly contain alluvial fan sediments on the eastern side of the MMAL site which slope up towards the fractured metamorphic rocks of the Southern Mount Lofty Ranges. The change in relief on-site is approximately 22 metres from the northwest corner of the MMAL site (39 m AHD) to the eastern boundary near the intersection of Main South Road and Shepherds Hill Road (61m AHD).

3.2.1 Topography and Drainage

Natural drainage of the area is dominated by the Sturt River, located 660m west of the western MMAL site boundary. The Sturt River was a meandering stream channel across the Adelaide Plains, until 1965 when it was straightened, and concrete lined for flood control. Flood control dams were also constructed during the same period, with one built southwest of the MMAL site near the intersection of the Sturt River and Sturt Road. The concrete lining begins at the dam (Sturt Road, Bedford Park) and continues to the entry of the Patawalonga Lake (Glenelg North). The location of the original river channel is depicted on **Figure F2**, based on aerial photographs from 1959 (PB 2008, Stage 1 ESA).

An intermittent water feature noted as Viaduct Creek flows from the Southern Mount Lofty Ranges (Shepherds Hill Recreation Park) during wet periods, into a concrete box culvert that flows beneath the north-eastern boundary of the MMAL site and continues underground until discharging to the Sturt River (**Figure F2**). This culverted stream receives most of the stormwater from the MMAL site.

The Audit area known as EPA Designated Source Area 3 lies within Section 14. This area has historically remained largely undeveloped apart from a rail spur line and some hardstand. The area currently consists of flat open land, largely covered with grass and weeds apart from some remnant bitumen hardstand.

The Audit area known as EPA Designated Source Area 4 encompasses portions of Sections 19b, 18 and 17 of the former MMAL site. Most of this area has recently been redeveloped by the Department for Planning, Transport and Infrastructure (DPTI) as a park-and-ride car park and is covered with relatively recently laid bitumen hard stand. A small area in the north of the audit area is not part of the new car park and is not currently covered by bitumen.

3.2.2 Adjacent Land Use

Local land use is a mixture of predominantly residential use interspersed with a rail corridor and industrial manufacturing facilities. The most prominent industrial site is the Monroe facility (approximately 8 Ha) located up hydraulic gradient (south east) of the MMAL site at 1326-1378 South Road, Clovelly Park. The Monroe facility has operated as an automotive parts manufacturer since the 1950s (originally as WH Wylie and Sons). The Monroe facility is currently under a Site Contamination Audit for VCHs in groundwater and soil vapour. Numerous commercial and light industrial facilities, once part of the automotive supply chain, and the Jarvis Toyota vehicle sales are located to the east and north east of the MMAL site. Further details of surrounding land use are detailed within a previous site assessment (PB 2008a).

A passenger rail corridor is present along the western boundary of the MMAL site, which previously connected to two rail spurs that ran into the southwest of the MMAL site.

The former R&C industrial site was located at 22-26 Ash Avenue and 7A Chestnut Court, Clovelly Park from 1963 to 1969. This site was located immediately south of the MMAL site and immediately west of the Monroe site. The activities and use of the R&C site have not been

definitively established. Post 1969, the site was sold to Chrysler (now MMAL), then later acquired for redevelopment into residential housing and open parkland (Chestnut Court Reserve). During 2010, the residents were relocated, and residential properties were demolished in response to potentially unacceptable risks from VCH vapour intrusion.

Voluntary residential relocation occurred during May 2014, as a result of further investigations regarding potentially unacceptable soil vapour risks from VCHs. The affected properties located along Chestnut Court and the north side of Ash Avenue have subsequently been demolished. This area is referred to as the “Relocation Area” (refer to **Figure F2**).

The MMAL site is currently undergoing various stages of development as an employment and educational hub. Residential development has been proposed for the north-western portion of the MMAL site, which is recently been subject to a Site Contamination Audit (defined in the VSCAP as the Residential Audit) (Mud, 2017) to meet the requirements of VSCAP Objective 5 and Objective 6.

3.3 Site History Summary

The site history information up to 2009 is well documented in previous assessments completed for the MMAL site, particularly the Phase 1 ESA (PB 2008a). A summary of the MMAL site history is provided below (after PB, 2008a):

- Prior to 1964 – agricultural land, partial ownership by Chrysler and WH Wylie and Sons;
- 1964 – production of motor vehicles and parts by Chrysler Australia, and later MMAL;
- Late 1960s – a southern parcel of land in Clovelly Park was sold to Reckitt and Coleman which operated a home and health care chemical manufacturing facility (**Figure F2**);
- Mid 1980s – former R&C property purchased by Unity Housing Apartments and Housing Units for renovation as residential purposes. It is noted in a previous assessment that the land subject to residential relocation on Ash Avenue and Chestnut Court was previously owned by Chrysler Australia (Fyfe 2014);
- Early 2000s – two houses built in the future Relocation Area by Housing SA (22A and 22B Ash Avenue);
- 2008 – MMAL plant closure begins in March; and
- 2009 – MMAL plant closed.

The MMAL site has been extensively redeveloped since the closure of the MMAL car manufacturing plant in 2009. The main vehicle assembly building encompassing Sections 10, 11, 12 and 13 has been extensively remodelled to accommodate the new TAFE facility and an associated technology precinct, while a number of new buildings have been constructed on the site. These include the Siemens building in Sections 7 and 8, the Flinders University building in Section 9 and the Department of State Development Drill Core Reference Library building in Sections 6 and 7.

The north western section of the MMAL site (comprising Section 19a and portions of Sections 15, 16, 17 and 19b) has recently been audited and is currently being redeveloped for residential and commercial use.

As a consequence of extensive investigation in the section of Tonsley (formerly Clovelly Park) located immediately south of the former MMAL site, residents of a number of houses have been relocated. These houses have since been demolished. This area is known as the “Relocation Area” and is shown on **Figure F2**.

3.4 Potentially Contaminating Activities (PCAs) and Contaminants of Potential Concern (CoPC)

Historical potentially contaminating activities (PCAs) across the former MMAL site and surrounding areas have been addressed within the Stage 1 Environmental Site Assessment (PB, 2008a), the various section reports prepared by PB between 2008 and 2010, and the Conceptual Site Model (CSM) report (BlueSphere, 2017b). Many of these PCAs have been extensively investigated, and in some cases remediated, since 2008. Based on the known history of the site, the results of previous investigations, and the requirements of the VSCAP, key PCAs addressed as part of the broader VSCAP investigation process comprise the following:

- Use of TCE and related compounds (VCH) as solvents within the MMAL site and adjacent off-site areas;
- Use of other volatile organic compounds (VOCs) within the MMAL site;
- Storage and use of petroleum hydrocarbon (fuel) products within the MMAL site;
- Use of metals associated with car manufacturing processes on the MMAL site, particularly hexavalent chromium associated with the former metal plating plant; and
- The use of cyanide associated with the former metal plating plant.

As discussed in **Section 1.5**, based on the investigations previously conducted as part of the VSCAP, and other relevant investigations, CoPC addressed as part of this investigation included:

- VCH (as defined in the VSCAP); and
- Petroleum hydrocarbons (TRH and BTEXN compounds).

Selected samples were also analysed for biodegradation indicators.

3.5 Regional Geology and Hydrogeology

A detailed discussion of the regional geology and hydrogeology can be found in Section 4 of the CSM document (BlueSphere, 2017b). Details of groundwater use in the area, including a search of registered groundwater bores, can also be found in the CSM.

3.6 Conceptual Site Model (CSM)

Readers are referred to the CSM Report (Revision 3) (BlueSphere 2017b) for details of the conceptual site model as understood at the commencement of these works. This provides details of the MMAL site geology and hydrogeology, nature and extent of contamination, contaminant transport processes, and potential exposure pathways.

A short summary discussion of the groundwater elevation contours and the extent of VCH contamination in groundwater and soil vapour is provided below.

3.6.1 Groundwater Elevation Contours

An inferred groundwater elevation contour map and a series of inferred VCH concentration contour maps for groundwater and soil vapour were prepared for the CSM Report based on the data obtained from the precinct-wide groundwater and soil vapour monitoring event conducted by BlueSphere in 2015.

The groundwater elevation contour map generated from the 2015 gauging data (**Figure F9**) shows that the groundwater flow direction across the former MMAL site is generally in a westerly direction with flow direction turning slightly more north-westerly in Mitchell Park to the west of the MMAL site. It is noted that the groundwater contour lines are very tightly grouped to the south of the MMAL site, most notably in the vicinity of the former R&C site.

A further gauging round was conducted in September 2016 following the installation of 18 additional off-site groundwater monitoring wells in Mitchell Park and Marion. This gauging round

focused on off-site wells and wells along the western boundary of the MMAL site. The groundwater elevation contours produced from the 2016 gauging data (**Figure F10**) showed that the groundwater flow direction across the western boundary of the MMAL site was to the west, with the flow direction taking a pronounced turn to the north-west further down hydraulic gradient in Mitchell Park and Marion.

3.6.2 VCH in Groundwater

The dominant VCH species in groundwater within the MMAL site and the adjoining areas is TCE. The TCE breakdown products cis-1,2-DCE and (to a lesser extent) VC are also widely present in areas where substantial TCE impacts are noted. PCE is typically present at locations where relatively high TCE concentrations are present, although the PCE concentrations are generally two to three orders of magnitude lower than the TCE concentrations, suggesting that PCE may have been present at low concentrations in the TCE based solvents used in the area. 1,1-DCE is also present at relatively low concentrations at a limited number of locations.

A series of groundwater concentration contour plans for VCH, TRH (C₁₀-C₄₀ fraction) and benzene were generated for the Progress Factual Report No. 1 (BlueSphere, 2016a) using data groundwater contaminant concentration data obtained by BlueSphere from July to October 2015. These concentration contour plans are included as **Appendix B**.

In order to provide a single figure for summary purposes, groundwater monitoring data from a number of sources has been combined to generate an indicative investigation area-wide inferred TCE groundwater concentration contour plan that covers the former MMAL site (including the Residential Audit area), the Monroe site, Tonsley to the south of the MMAL site, and the suburbs of Mitchell Park and Marion to the west of the MMAL site. This contour plan is presented as **Figure F12**. The groundwater TCE concentration data used to construct the figure was obtained from the following sources:

- Data from the MMAL site and Tonsley to the south obtained by BlueSphere from July to October 2015;
- Data from off-site monitoring wells to the west of MMAL obtained by BlueSphere in September 2016 following the installation of 18 additional off-site groundwater monitoring wells;
- Data from the Monroe site obtained by URS (now AECOM) in May 2015; and
- Data from the Residential Audit area obtained by Greencap in June 2014 and August 2015.

It should be noted that **Figure F12** has been constructed using various overlapping data sets collected at different times and is intended only to provide a general overview of the approximate distribution of TCE in groundwater across the various properties and investigation areas in the vicinity of the former MMAL site. It should not be relied upon as a point in time comparison of TCE concentrations due to the temporal variability of the data sets.

The following key features are noted regarding groundwater conditions from **Figure F12**:

- Two areas of very high TCE concentrations in groundwater (ranging within 10,000 – 30,000 µg/L) are present at the southern and northern ends of the Monroe site;
- An area comprising high TCE concentrations in groundwater (ranging within 1,000 – 9,999 µg/L) is centred on the former R&C site;
- An area of high TCE concentrations in groundwater (ranging within 1,000 – 9,999 µg/L) is located in the MMAL site immediately south of the TAFE building;
- A large area of high TCE concentrations in groundwater (ranging within 1,000 – 9,999 µg/L) is present around the south-western corner of the MMAL site which extends a short distance (approximately 100m) into Mitchell Park;
- A large finger-shaped area of moderately elevated TCE concentrations in groundwater (ranging between 100 – 999 µg/L) extends beneath the TAFE building, across the southern end of EPA Designated Source Area 4 into Mitchell Park;

- A separated finger-shaped area of moderately elevated TCE concentrations in groundwater (ranging between 100 – 999 µg/L) extends from near the north-east corner of Source Area 4, across the northern section of EPA Designated Source Area 4 into Mitchell Park;
- Some areas of minor TCE impacts in groundwater (ranging between 10 – 99 µg/L) are present in the northern portion of the MMAL site, with possible migration of off-site sourced TCE onto the site in the north-eastern corner of the MMAL site;
- An area of very low TCE concentrations in groundwater (< 10 µg/L) is present between EPA Designated Source Area 3 and EPA Designated Source Area 4;
- Low TCE concentration in groundwater is present along the line of Bradley Grove approximately 120 m west of the MMAL site boundary, running in a north south orientation; and
- A zone of higher TCE concentrations in groundwater (ranging between 100 – 999 µg/L) is present approximately 100 m west of Bradley Grove. The TCE impacts present in this area appear to extend in a continuous plume to the north-west for a distance of approximately 1.3 km.

The respective sources of these areas of VCH impact, and the interconnection between them, was not fully understood at the time that the CSM report (Revision 03) was finalised (BlueSphere, 2017b).

3.6.3 VCH in Soil Vapour

The primary VCH species present in soil vapour was TCE with lower concentrations of the degradation products (cis-1,2-DCE and VC) as well as PCE and 1,1-DCE seen at some locations. This correlates with the primary VCH species present in groundwater.

Prior to the commencement of this investigation, limited soil vapour data was available for the MMAL site other than within Section 14 in the far south of the MMAL site. As part of the Progress Factual Report No. 1 (BlueSphere, 2016a), VCH soil vapour data obtained by BlueSphere from July to September 2015, plus some data obtained by Fyfe in April 2015 (Fyfe, 2015) was used to generate soil vapour TCE concentration contour plans for soil vapour at depths of 2 m, 4 m and 8 m as well as for DCE at 2m. It is noted that the relatively small number of data points available across Section 14 and the area to the south of the MMAL site resulted in a lower level of spatial resolution than is seen in the groundwater TCE contour plan (**Figure F12**).

The best indication of the approximate extent of shallow soil vapour impacts is provided by the TCE contour plan for shallow soil vapour at 2.0 m to 2.3 m bgl. This figure is presented as **Figure F13**. The other concentration contour plans (as presented in BlueSphere, 2016a) are provided in **Appendix C**. The following key points are noted from **Figure F13** with respect to the distribution of VCH vapours in shallow soil vapour:

- A band of very high soil vapour TCE concentrations (from 1,000 to 100,000 µg/m³) is present across the former R&C site, the Relocation area and the southern boundary of the MMAL site. This is generally consistent with the very high groundwater TCE concentrations seen in these areas;
- Lobes of moderately elevated soil vapour TCE concentrations (ranging between 100 – 1,200 µg/m³) are present and extend approximately 50 to 100 m into Mitchell Park from the south-western corner of the MMAL site (EPA Designated Source Area 3) and from the northern portion of EPA Designated Source Area 4;
- A lobe of slightly elevated TCE concentrations (ranging between 10 – 100 µg/m³) in soil vapour extends into Mitchell Park from the area between EPA Designated Source Areas 3 and 4;
- A zone of TCE soil vapour concentrations (below the laboratory LOR) is present along the line of Bradley Grove; and

- Consistent with the groundwater data, higher TCE soil vapour concentrations (up to 300 $\mu\text{g}/\text{m}^3$) are present to the west of Bradley Grove, with the zone of elevated TCE concentrations extending to the north-west.

It is noted that the distribution of TCE in soil vapour shown on **Figure F13**, is generally consistent with the distribution of TCE in groundwater as represented on **Figure F12**.

4 Data Quality Objectives

The data quality objective (DQO) process as outlined in the ASC NEPM were applied in the development of the SAQP and the subsequent implementation of the program. The DQOs selected for this investigation were selected to ensure that the data collected was appropriate to meet the objectives of the investigation as set out in the VSCAP and listed in **Section 1.5** above.

The key steps of the DQO process can be summarised as follows:

- State the problem;
- Identify the decision;
- Identify inputs to the decision;
- Define the study boundaries;
- Develop a decision rule;
- Specify the limits on decisions errors; and
- Optimise the design.

Each of these steps is discussed in turn in the following sections.

4.1 State the Problem

Extensive groundwater and soil vapour investigations have been conducted across the MMAL site and adjacent areas since 2008. However, a number of data gaps remained with respect to the effective characterisation of the current nature and extent of the groundwater and soil vapour impacts on-site and off-site to the west, and with respect to the understanding of the nature of the upper Quaternary aquifer beneath the MMAL site. The identified data gaps relevant to this investigation were:

- There was insufficient off-site groundwater VCH concentration data to provide confidence that the nature and extent of the off-site VCH plume to the west of the MMAL site in Mitchell Park and Marion had been reliably delineated. This is particularly true of the area to the north of Alawoona Avenue where the monitoring wells installed in 2016 had only been sampled only once or twice.
- There was insufficient off-site soil vapour data to provide confidence that the soil vapour conditions to the west of the MMAL site in Mitchell Park had been adequately characterised, including data collected under both winter/spring and summer/autumn conditions.
- A comprehensive groundwater and soil vapour monitoring event had not been conducted across the southern half of the former MMAL site, incorporating much of the Audit areas (EPA Designated Source Areas 3 and 4), since October 2015. Hence, additional data was required to confirm and improve the current understanding of the nature and extent of VCH contamination in groundwater and soil vapour within the southern half of the MMAL site.
- The current understanding of the geology or architecture of the saturated zone in the upper Quaternary aquifer beneath the MMAL site and surrounding areas is incomplete. There is an apparent contradiction between the observed length of the off-Site VCH groundwater plume and existing bulk hydraulic conductivity data, and uncertainty regarding the linkages between source areas and the observed groundwater plumes. This may be explained by the presence of previously unreported thin, high conductivity aquifer units within the predominantly clay matrix of the upper Quaternary aquifer.

It is noted that there is considerable community sensitivity around contamination in the Clovelly Park / Mitchell Park area and these sensitivities must be considered at all stages of the assessment process. The EPA and Renewal SA have initiated and maintained a comprehensive community consultation program with residents in the area around the MMAL site. Similarly, Renewal SA has a consultation process in place for users of the MMAL site. BlueSphere has

liaised through Renewal SA to ensure all works on the MMAL site or surrounding areas are conducted in accordance with the respective community consultation plans.

4.2 Identify the Decision

The following decisions are to be made on the basis of the data collected from this investigation:

- Has the current nature and extent of the off-site groundwater VCH plume to the west of the site been characterised with sufficient confidence to adequately assess the risks to human health and the environment?
- Does the on-site groundwater monitoring data provide sufficient confidence that the nature and extent of the VCH groundwater impacts within the former MMAL site are adequately understood for the purposes of the Audit?
- Has the current nature and extent of the off-site soil vapour impacts to the west of the MMAL site been characterised with sufficient confidence, under both winter/spring and summer/autumn conditions, to adequately assess the risks to human health?
- Does the on-site soil vapour monitoring data provide sufficient confidence that the nature and extent of the VCH soil vapour impacts within the former MMAL site are adequately understood for the purposes of the Audit?
- Does the data from the downhole geophysical logging assist in further developing an understanding of the upper Quaternary aquifer architecture?

4.3 Identify Inputs to the Decision

Key inputs to the decision making process include the following:

- Existing groundwater and soil vapour monitoring data presented in the reports listed in Section 2 of the SAQP;
- Consideration of the investigation area-wide CSM (incorporating the MMAL site, the Monroe site and the surrounding residential areas in Tonsley (formerly Clovelly Park) and Mitchell Park) developed by BlueSphere (2017b);
- Results of groundwater gauging, field measurements, sampling and laboratory analysis of existing groundwater monitoring wells and new and existing soil vapour bores conducted by BlueSphere as part of this investigation;
- Tier 1 assessment criteria for groundwater and soil vapour as described in Section 5 of the SAQP (BlueSphere, 2017c);
- Data from previous downhole geophysical data of groundwater monitoring wells conducted in 2015 (BlueSphere, 2016a); and
- Results of downhole geophysical data conducted as part of this investigation.

4.4 Define the Study Boundary

The lateral boundary of the study area, labelled “the investigation area”, is defined as:

- All of the former MMAL site, with the exception of the Residential Audit area;
- The sections of Mitchell Park and Marion lying to the west of the former MMAL site bounded by:
 - The Tonsley rail corridor to the east;
 - Sturt Road to the south;
 - The Sturt River and the Noarlunga railway corridor to the west (with the addition of a small area of park between the south-western end of Minchinbury Avenue and the Sturt River); and

- Avalon Road and Hamilton Secondary College to the north.
- The section of Tonsley lying to the south of the former MMAL site bounded by:
 - The former MMAL site to the north and west;
 - Ash Avenue to the south; and
 - The Monroe site to the east.

The vertical boundary of this study is confined to the uppermost Quaternary (water table) aquifer.

The study was determined temporally by the requirement to obtain soil vapour data when the water table is relatively high (late winter or spring) and at a time when the water table is likely to be relatively low (late summer / autumn). Therefore, the investigation timeframe extended from November 2017 to April 2018.

The study is limited to the aspects in the restricted scope Site Contamination Audit.

The Audit is restricted to elements of the environment including soil vapour and water, and specifically excludes elements of soil, sediments, air, organisms, ecosystems, human-made or modified structures or areas, and amenity values (e.g. odour, aesthetics). The Audit is restricted to chemical substances associated with motor vehicle manufacture including volatile chlorinated hydrocarbons (VCH), daughter products and petroleum hydrocarbons.

The following aspects and activities are excluded from the restricted scope Audit:

- Determination of suitability for sensitive or other land uses;
- Deep aquifers, below the water table aquifer e.g. deeper Quaternary and Tertiary aquifers. This audit is restricted to the assessment of the water table Quaternary aquifer from which volatile contaminants can be emitted into the vadose zone;
- Chemical substances not associated with the motor vehicle manufacture activities that may have been previously used at the MMAL site;
- Nature, extent and potential risk associated with soil-adsorbed impacts; and
- Community engagement and associated communication activities.

4.5 Develop a Decision Rule

The following decision rules were applied to the decisions listed in **Section 4.2**:

- The current groundwater VCH conditions (both on-site and off-site) were considered to be reliably characterised at a particular groundwater monitoring well location if:
 - The groundwater well had been sampled and analysed for VCH on at least three occasions; and
 - The TCE concentration and the total VCH concentration for the most recent monitoring event lay within 50% of the mean of the last three events, or they lay within 10 µg/L of the mean of the three events.
- For groundwater wells where the data showed a clear monotonic increasing trend in TCE concentration over the last three monitoring rounds (or a statistically significant increasing trend at the 95% confidence level where five or more data points are available), an increasing concentration trend may be present. In this case, an assessment of the significance of the data was made in the context of the associated uncertainty in the assessment of risk to human health and the environment. Where the level of uncertainty is considered to be unacceptable, additional sampling was recommended.
- Where a possible decreasing trend was indicated, further sampling was not undertaken as the data was considered to provide an upper bound estimate from a risk perspective.

- Determination of the reliability of on-site and off-site soil vapour VCH concentrations at each soil vapour bore was determined using the same criteria as groundwater VCH concentrations, noting that the data set was required to include data measured in November 2017 under spring conditions and in March 2018 under autumn conditions.
- Where groundwater or soil vapour data from the first round of sampling fell outside the limits specified for satisfactory characterisation, an assessment of the significance of the outlier was made in the context of the associated uncertainty in the assessment of risk to human health and the environment. Where the level of uncertainty is considered to be unacceptable a second round of sampling was conducted.

All laboratory data used in the decision making process was subject to a stringent data validation process involving consideration of holding times, transportation temperatures, canister pressures, rinsate blanks, trip blanks, intra and inter-laboratory field duplicates, and laboratory QA/QC samples.

Acceptance limits for the specified QA/QC procedures are listed in **Table 3** below.

Table 3 Data Quality Procedures and Acceptability Limits

Data Quality Procedure	Data Quality Objective	Acceptability Limits	Reference
Field Calibration	All instruments to be calibrated correctly prior to use in field.	Field instrumentation calibrated prior to use. Calibration certificates and records documented.	AS4482.1-2005 NEPM (1999) Schedule B(2)
Sample Preservation and Storage	Samples preserved, stored and transported in a manner such that sample integrity is maintained.	0-4 degrees for water samples.	AS4482.1-2005, ASC NEPM (Schedule B3)
Canister Pressure	Negative canister pressures should be maintained during transport, to indicate that canisters haven't leaked excessively.	Canister pressure on receipt by the laboratory should be negative and not vary by more than 5" Hg from the pressure upon despatch (noting that ± 5 " Hg is the typical accuracy of the canister gauges).	CRC Care Technical Report 23
Frequency of Quality Control Measurements	Field blanks, field duplicates and triplicates are above minimum requirements.	Field duplicate and field triplicate samples at one per 20 samples collected. One rinsate blank per equipment per day requiring decontamination. One trip blank per esky where volatiles are CoPC. Field blanks as required on a project basis.	AS4482.1-2005, ASC NEPM (Schedule B3)
Field Duplicates	Relative percentage difference (RPD) between duplicate sample and parent samples within acceptable range.	Results $> 10 \times \text{LOR} = \text{RPD}$ between 0-30% for water and soil vapour. Compliance rate $> 95\%$ of samples. (Where results $< 10 \times \text{LOR} = \text{no RPD}$ range was applied in recognition of the low absolute differences at these concentrations).	ASC NEPM (Schedule B3)

Table 3 Data Quality Procedures and Acceptability Limits

Data Quality Procedure	Data Quality Objective	Acceptability Limits	Reference
Field Triplicates	RPD between duplicate sample and parent sample within acceptable range.	Results >10 x LOR = RPD between 0-30% for water and soil vapour. Compliance rate > 95% of samples. (Where results <10 x LOR = no RPD range was applied in recognition of the low absolute differences at these concentrations).	ASC NEPM (Schedule B3)
Rinsate Blanks	Analytes reported at concentrations below the laboratory limit of reporting.	<LOR	AS4482.1-2005, ASC NEPM (Schedule B2)
Trip Blanks	Analytes reported at concentrations below the laboratory limit of reporting.	<LOR	AS4482.1-2005, ASC NEPM (Schedule B2)

The downhole geophysical logging data was considered sufficient for the purposes of the assessment if it provided sufficient data, in conjunction with the other lines of evidence, regarding the architecture of the uppermost Quaternary aquifer to provide an understanding of the migration of groundwater and associated contamination in the vicinity of the VCH plume.

4.6 Specify Limits on Decision Errors

Statistical limits applied in the decision making process for determining whether groundwater and soil vapour conditions have been adequately and reliably characterised are clearly stated in **Section 4.5** (Decision Rules). Where data did not comply with the specified statistical limits, an assessment of the significance of the outlier was made and recommendations made for additional sampling if the degree of uncertainty was considered unacceptable.

Decision errors in the context of this investigation can take the form of Type 1 errors (i.e. deciding that a location is acceptable when it is in fact not compliant) or Type 2 errors (i.e. deciding a location is unacceptable when it is in fact compliant). In the context of a site contamination investigation, Type 2 errors are far more acceptable and can subsequently be corrected via additional targeted investigation. Typically, the error limit set for Type 1 errors is 5% and the error limit for Type 2 errors it is 20%.

Statistical analysis of data errors can be conducted on single data sets. This approach was used to assess whether contaminant concentrations in groundwater and soil vapour have been reliably determined.

Often, direct statistical analysis of decision errors is not possible for a complex multi-faceted investigation of this nature. Thus, professional judgement must be used in identifying the nature and extent of site contamination. However, it is noted that decisions regarding the nature and extent of site contamination are to be made on the basis of a large number of data points gathered from numerous sampling locations distributed both laterally and vertically, often obtained over multiple sampling rounds. Rigorous QA/QC methods are applied to ensure the reliability of data sets generated as part of this investigation.

Furthermore, a multiple lines of evidence approach considering the distribution of contaminants within groundwater and soil vapour was used. Careful comparison of the various lines of evidence was undertaken and conflicting conclusions from different lines of evidence (e.g. groundwater, soil vapour and soil data) highlighted as potentially indicative of decision errors and investigated further. Significant variations in reported concentrations relative to historical data at the same

location were also be highlighted as potentially identifying anomalous or incorrect data points and triggered further investigation.

Appropriate levels of conservatism have been applied to the interpretation of these data to provide a high level of confidence that significant levels of contamination originating from the MMAL site (or the Audit areas as appropriate) are not present outside of the limits determined by this investigation.

4.7 Optimise the Design

In order to meet the objectives of the investigation, and support the decision making process described above, an investigation design strategy was developed in conjunction with the Auditor. It is noted that some changes to the proposed strategy were subsequently required due to the loss or decommissioning of groundwater wells, primarily as a consequence of the on-going development works on the former MMAL site. The key elements of the proposed strategy are listed below.

4.7.1 On-Site Groundwater Investigations

- Gauging of 53 selected on-site groundwater monitoring wells within the former MMAL site (**Figure F4**). This includes all active groundwater monitoring wells on the southern half of the MMAL site and a selection of groundwater monitoring wells in the northern part of the MMAL site to provide sufficient spatial coverage to construct investigation area-wide groundwater elevation contours. It is noted that many groundwater monitoring wells located in the northern portion of the MMAL site have been decommissioned. In particular, most of the groundwater monitoring wells located within and adjacent to the Residential Audit Area were decommissioned in 2017 as a result of site development works. All remaining on-site groundwater monitoring wells are shown on **Figure F4**.
- Sampling of 31 existing groundwater monitoring wells within the southern part of the former MMAL site (**Figure F4**). These wells have been selected to provide sufficient spatial coverage over the known areas of VCH impacts in groundwater. The selected locations have targeted the following areas:
 - The areas of elevated groundwater VCH concentrations extending across the southern part of Section 14, including Source Area 3;
 - The zone of elevated VCH concentrations extending beneath the former Main Assembly Building (now the TAFE building) into EPA Designated Source Area 4; and
 - The zone of elevated VCH concentrations extending across the northern part of EPA Designated Source Area 4.
- Resampling of any on-site groundwater monitoring wells where the data does not provide sufficient confidence that the groundwater conditions have been reliably established.

4.7.2 Off-Site Groundwater Investigations

- Gauging of all available off-site groundwater monitoring wells to the west and south of the former MMAL site (**Figure F5**);
- Sampling and analysis for VCH of all accessible off-site groundwater monitoring wells installed to the north of Alawoona Avenue by BlueSphere in 2016 (BSE_DW01 to BSE_DW18) (**Figure F5**);
- Sampling and analysis for VCH of approximately 20 older off-site groundwater monitoring wells located in Mitchell Park to the south of Alawoona Avenue (**Figure F5**). These have been selected to include all wells located within the plume, and delineating wells located immediately outside the known extent of the plume. A small number of wells in Mitchell Park located well outside the known extent of the plume have been excluded;
- Sampling and analysis for VCH of four existing off-site groundwater monitoring wells located within the Relocation Area and the former R&C Colman site to the south of the former MMAL

site (**Figure F5**). It is noted that the other groundwater wells in this area have proven to be consistently dry over recent years; and

- Resampling as part of the second sampling round of the nine off-site wells that have only been sampled once prior to this investigation (BSE_DW10 to BSE_DW18) and any other off-site groundwater monitoring wells where the data from Round 1 does not provide sufficient confidence that the groundwater conditions have been reliably established.

4.7.3 On-Site Soil Vapour

- Installation and sampling of three sets of nested on-site soil vapour bores within EPA Designated Source Area 4 and two sets of nested wells in EPA Designated Source Area 3 (**Figure F6**);
- Sampling of approximately 13 existing on-site soil vapour bores within and immediately adjacent to EPA Designated Source Area 3 (**Figure F6**); and
- Resampling of any on-site soil vapour bores where the Round 1 data does not provide sufficient confidence that the soil vapour conditions have been reliably established.

4.7.4 Off-Site Soil Vapour

- Sampling in November 2017, (under spring conditions) of approximately 23 existing off-site soil vapour bores in the most impacted areas immediately west of the MMAL site (**Figure F7**). These soil vapour bores have been selected to target areas of elevated soil vapour VCH concentrations. The targeted areas are centred on the following soil vapour bores:
 - SV_EPA33 (adjacent EPA Designated Source Area 4),
 - SV_EPA34 (adjacent EPA Designated Source Area 3);
 - SV_EPA40 (further west on Kelsey Avenue); and
 - SV_EPA30 (between EPA Designated Source Areas 3 and 4).
- Resampling in March 2018 (under autumn conditions) of the selected off-site soil vapour bores.

4.7.5 Geophysical Logging

Geophysical logging of 23 existing groundwater monitoring wells (**Figure F8**). All wells will be logged using a natural gamma probe and seven selected wells will also be logged using an induction (conductivity) probe. The selected wells comprise 18 off-site wells to the west of the MMAL site in Mitchell Park and Marion, three off-site wells to the south of the MMAL site in Tonsley, and two wells located in Section 14 of the MMAL site.

5 Scope of Work

The following works were conducted between November 2017 and April 2018. Where the works undertaken differed from the proposed investigation plan described in **Section 4.7**, the nature of the deviation and the reason for the change is provided.

5.1 First Sampling Round (November 2017 to February 2018)

The first round of soil vapour sampling was conducted in November 2017. Groundwater gauging was conducted in November and December 2017 with the first round of groundwater sampling conducted in January and February 2018. Details of the work undertaken are provided below.

5.1.1 On-Site Groundwater

The first round of on-site groundwater investigations comprised the following:

- Gauging of 53 on-site groundwater monitoring wells in a single gauging round with an interface meter (19 wells nominated in the SAQP could not be gauged due to extensive decommissioning of wells in the northern part of the MMAL site);
- Sampling of 31 on-site groundwater monitoring wells using a low-flow sampling methodology (three nominated wells could not be sampled as two wells had been destroyed and one well contained insufficient water); and
- Analysis of all samples for VCH and selected samples for TRH/BTEX and biodegradation indicators (based on previous evidence of the presence of petroleum hydrocarbons).

The on-site groundwater monitoring wells gauged and sampled are shown on **Figure F4**. The sampling and analysis schedule for on-site groundwater wells is shown in **Table 4**.

Table 4 On-Site Groundwater Sampling and Analysis Schedule

Well ID	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
BSE_GW01	✓	VCH, TRH/BTEX, Biodeg	✓	VCH, TRH/BTEX
BSE_GW02	✓	VCH, TRH/BTEX, Biodeg	✓	VCH, TRH/BTEX
BSE_GW03	✓	VCH, TRH/BTEX, Biodeg	✓	VCH, TRH/BTEX
BSE_GW04	✓	VCH, TRH/BTEX, Biodeg	✓	VCH, TRH/BTEX
BSE_GW05	✓	VCH, TRH/BTEX, Biodeg	✓	VCH, TRH/BTEX
BSE_GW06	✓	VCH	✓	VCH
BSE_GW07	✓	VCH	✓	VCH
BSE_GW08	✓	VCH	x	-
BSE_GW09	✓	VCH	✓	VCH
BSE_GW10	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
GW22	dry			
GW38_URS	lost			
GW39_URS	✓	VCH	x	-
GW40_URS	✓	VCH	x	-
GW41_URS	✓	VCH, TRH/BTEX, Biodeg	x	-
GW42_URS	✓	VCH, TRH/BTEX	✓	VCH
GW43_URS	✓	VCH, TRH/BTEX, Biodeg	✓	VCH

Table 4 On-Site Groundwater Sampling and Analysis Schedule

Well ID	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
GW44_URS	✓	VCH	✓	VCH
MWS11_01	✓	VCH, TRH/BTEX, Biodeg	✓	VCH
MWS11_03	✓	VCH, TRH/BTEX	✓	VCH
MWS13_01	✓	VCH	x	-
MWS14_01	✓	VCH	x	-
MWS14_06	lost			
MWS14_08	✓	VCH	x	-
MWS14_09	✓	VCH	x	-
MWS17_01A	✓	VCH, TRH/BTEX	✓	VCH
MWS17_06	✓	VCH	✓	VCH
MWS17_07	✓	VCH, TRH/BTEX	✓	VCH
MWS18_02A	✓	VCH, TRH/BTEX	✓	VCH
MWS18_06	✓	VCH	x	-
MWS18_07	✓	VCH	x	-
URS02	✓	VCH	x	-
URS03	✓	VCH	x	-
URS06	✓	VCH, TRH/BTEX	x	-
TOTAL	31		18	

5.1.2 Off-Site Groundwater

The first round of off-site groundwater investigations comprised the following:

- Gauging of 56 off-site groundwater monitoring wells in a single gauging round (at the same time as the on-site wells) with an interface meter (two nominated wells could not be gauged as they had been decommissioned or lost);
- Sampling of 41 off-site groundwater monitoring wells using a low-flow sampling methodology (three nominated wells could not be sampled as one had been decommissioned, one could not be located, and another was covered with construction material); and
- Analysis of all samples for VCH.

The off-site groundwater monitoring wells gauged and sampled are shown on **Figure F5**. The sampling and analysis schedule for off-site groundwater wells is shown in **Table 5**.

Table 5 Off-Site Groundwater Sampling and Analysis Schedule

Well ID	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
BSE_DW01	✓	VCH	x	VCH
BSE_DW02	✓	VCH	✓	VCH
BSE_DW03	✓	VCH	✓	VCH
BSE_DW04	✓	VCH	x	VCH

Table 5 Off-Site Groundwater Sampling and Analysis Schedule

Well ID	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
BSE_DW05	✓	VCH	x	VCH
BSE_DW06	✓	VCH	x	VCH
BSE_DW07	✓	VCH	x	VCH
BSE_DW08	✓	VCH	x	VCH
BSE_DW09	✓	VCH	x	VCH
BSE_DW10	lost			
BSE_DW11	✓	VCH	✓	VCH
BSE_DW12	✓	VCH	✓	VCH
BSE_DW13	✓	VCH	✓	VCH
BSE_DW14	✓	VCH	✓	VCH
BSE_DW15	✓	VCH	✓	VCH
BSE_DW16	Temporarily covered with building rubble		✓	VCH
BSE_DW17	✓	VCH	✓	VCH
BSE_DW18	✓	VCH	✓	VCH
MW_EPA1	✓	VCH	x	VCH
MW_EPA2	✓	VCH	✓	VCH
MW_EPA10A	✓	VCH	✓	VCH
MW_EPA11	✓	VCH	✓	VCH
MW_EPA12	✓	VCH	✓	VCH
MW_EPA13	✓	VCH	✓	VCH
MW_EPA14	✓	VCH	x	VCH
MW_EPA15	✓	VCH	x	VCH
MW_EPA16	✓	VCH	x	VCH
MW_EPA17	decommissioned			
MW_EPA18	✓	VCH	x	VCH
MW_EPA19	✓	VCH	x	VCH
MW_EPA20	✓	VCH	x	VCH
MW_EPA21	✓	VCH	x	VCH
MW_EPA22	✓	VCH	x	VCH
MW_EPA23	✓	VCH	x	VCH
MW_EPA24	✓	VCH	x	VCH
MW_EPA26	✓	VCH	x	VCH
MW_EPA29	✓	VCH	✓	VCH
MW_EPA30	✓	VCH	x	VCH
MW_EPA31	✓	VCH	x	VCH
MW_EPA32	✓	VCH	x	VCH
MW_EPA33	✓	VCH	x	VCH

Table 5 Off-Site Groundwater Sampling and Analysis Schedule

Well ID	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
MWS14_13	✓	VCH	x	VCH
W5	✓	VCH	x	VCH
GGW1	✓	VCH	✓	VCH
TOTAL	41		16	

5.1.3 On-Site Soil Vapour

The first round of on-site soil vapour investigations comprised the following:

- Installation of five sets of three nested soil vapour bores screened at approximately 2 m, 4 m and 8 m bgl (15 bores on total). Three sets of bores were installed within EPA Designated Source Area 4 and two sets in EPA Designated Source Area 3;
- Sampling of the 15 newly installed on-site soil vapour bores;
- Sampling of 13 existing soil vapour bores within and immediately adjacent to EPA Designated Source Area 3 (four nominated bores could not be located, so an additional two bores were identified within the proximity to be sampled); and
- Analysis of all soil vapour samples for VCH and selected samples for TRH/BTEX (based on previous evidence of the presence of petroleum hydrocarbons).

The locations of the new on-site soil vapour bores and the existing bores that were sampled are shown on **Figure F6**. The sampling and analysis schedule for on-site soil vapour bores is shown in **Table 6**.

Table 6 On-Site Soil Vapour Sampling and Analysis Schedule

Bore ID	Depth (m)	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
BSE_SV01A	2	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV01B	4	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV01C	8	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV02A	2	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV02B	4	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV02C	8	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV03A	2	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV03B	4	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV03C	8	✓	VCH, TRH/BTEX	✓	VCH, TRH/BTEX
BSE_SV04A	2	✓	VCH	✓	VCH
BSE_SV04B	4	✓	VCH	✓	VCH
BSE_SV04C	8	✓	VCH	✓	VCH
BSE_SV05A	2	✓	VCH	✓	VCH
BSE_SV05B	4	✓	VCH	✓	VCH
BSE_SV05C	8	✓	VCH	✓	VCH
SV01	4	✓	VCH, TRH/BTEX	✓	VCH

Table 6 On-Site Soil Vapour Sampling and Analysis Schedule

Bore ID	Depth (m)	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
SV02	4	✓	VCH	x	-
SV06	4	✓	VCH	x	-
SV07	4	✓	VCH	x	-
SV13_1M	1	✓	VCH	✓	VCH
SV13_2M	2	✓	VCH	✓	VCH
SV13_4M	4	✓	VCH	✓	VCH
SV13_6M	6	✓	VCH	✓	VCH
SV31	4	✓	VCH, TRH/BTEX	x	-
SV1000	2	✓	VCH	x	-
SV_EPA60A	2	✓	VCH, TRH/BTEX	x	-
SV_EPA62A	2	✓	VCH, TRH/BTEX	✓	VCH
SV_EPA64A	2	Lost (subsequently located for Round 2)		✓	VCH
SV_EPA64B	4	Lost (subsequently located for Round 2)		✓	VCH
SV_EPA64C	8	Lost (subsequently located for Round 2)		✓	VCH
SV_EPA66	2	✓	VCH	✓	VCH
SV_EPA67	2	Lost			
TOTAL		28		25	

5.1.4 Off-Site Soil Vapour

The first round of off-site soil vapour sampling comprised the following:

- Sampling of 23 existing off-site soil vapour bores (at 17 locations, including 6 nested pairs) located to the west of the former MMAL site. One nominated bore was found to be destroyed and an alternative bore within the vicinity was sampled instead; and
- Analysis of all soil vapour samples for VCH.

The locations of the off-site soil vapour bores that were sampled are shown on **Figure F7**. The sampling and analysis schedule for on-site soil vapour bores is shown in **Table 7**.

Table 7 Off-Site Soil Vapour Sampling and Analysis Schedule

Bore ID	Depth (m)	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
SV_EPA26	2	x	-	✓	VCH
SV_EPA27	2	✓	VCH	✓	VCH
SV_EPA30	2	✓	VCH	✓	VCH
SV_EPA32	2	✓	VCH	✓	VCH
SV_EPA33A	2	✓	VCH	✓	VCH
SV_EPA33B	4	✓	VCH	✓	VCH
SV_EPA34A	2	✓	VCH	✓	VCH
SV_EPA34B	4	✓	VCH	✓	VCH

Table 7 Off-Site Soil Vapour Sampling and Analysis Schedule

Bore ID	Depth (m)	Sampled Round 1	Analyses Round 1	Sampled Round 2	Analyses Round 2
SV_EPA35A	2	✓	VCH	✓	VCH
SV_EPA35B	4	✓	VCH	✓	VCH
SV_EPA40A	2	✓	VCH	✓	VCH
SV_EPA40B	4	✓	VCH	✓	VCH
SV_EPA42	2	✓	VCH	✓	VCH
SV_EPA49	2	✓	VCH	✓	VCH
SV_EPA51	2	✓	VCH	✓	VCH
SV_EPA52	2	✓	VCH	✓	VCH
SV_EPA54A	2	✓	VCH	✓	VCH
SV_EPA56	2	✓	VCH	✓	VCH
SV_EPA57A	2	✓	VCH	✓	VCH
SV_EPA76A	2	✓	VCH	x	-
SV_EPA76B	4	✓	VCH	x	-
SV_EPA78A	2	✓	VCH	✓	VCH
SV_EPA78B	4	✓	VCH	✓	VCH
SV_EPA80	4	✓	VCH	✓	VCH
TOTAL		23		22	

5.2 Second Sampling Round

The scope of the second sampling rounds for both groundwater and soil vapour were determined on the basis of the stability/ reliability analysis conducted at the conclusion of the first round of sampling. The results of the analysis, and the groundwater wells and soil vapour bores selected for re-sampling, are discussed in **Section 9.2** and **Section 10.1**.

5.2.1 On-Site Groundwater

The second round of on-site groundwater sampling comprised:

- Re-sampling of 18 on-site groundwater monitoring wells, using the low-flow sampling method, that were not considered to be reliably characterised following the first round of sampling; and
- Analysis of all samples for VCH and selected samples for TRH/BTEX and biodegradation indicators (based on previous evidence of the presence of petroleum hydrocarbons).

5.2.2 Off-Site Groundwater

The second round of off-site groundwater sampling comprised:

- Re-sampling of 17 off-site groundwater monitoring wells that were not considered to be reliably characterised following the first round of sampling; and
- Analysis of all samples for VCH.

5.2.3 On-Site Soil Vapour

The second round of on-site soil vapour sampling comprised:

- Re-sampling of the five sets of three on-site soil vapour bores installed in November as part of the first sampling round;

- Re-sampling of ten existing on-site soil vapour bores that were not considered to be reliably characterised following the first round of sampling; and
- Analysis of all soil vapour samples for VCH and selected samples for TRH/BTEX (based on previous evidence of the presence of petroleum hydrocarbons).

5.2.4 Off-Site Soil Vapour

The second round of off-site groundwater sampling comprised:

- Re-sampling and analysis for VCH of 22 soil vapour bores to provide Summer/ Autumn seasonal data; and
- Analysis of all soil vapour samples for VCH.

5.3 Downhole Geophysical Logging

The borehole geophysical logging program comprised the following:

- Natural gamma probe logging of 18 existing off-site groundwater monitoring wells to the west of the MMAL site in Mitchell Park and Marion. Five of the groundwater wells located along the centre line of the plume were also logged using an induction (conductivity) probe;
- Natural gamma probe logging of three existing off-Site groundwater monitoring wells to the south of the former MMAL site in Tonsley. One of the groundwater wells was also logged using an induction (conductivity) probe; and
- Natural gamma probe logging of two existing on-site groundwater monitoring wells within Section 14 of the former MMAL site. One of the groundwater wells was also logged using an induction (conductivity) probe.

A schedule listing the groundwater monitoring wells logged is provided in **Table 8**. The locations of the wells selected for geophysical logging are shown on **Figure F8**.

Table 8 Geophysical Logging Schedule

Bore ID	Installed by	Depth (m)	Gamma Logging	Induction Logging
Off-Site – Mitchell Park and Marion				
BSE_DW02	BlueSphere	12	✓	x
BSE_DW03	BlueSphere	13	✓	✓
BSE_DW07	BlueSphere	11	✓	x
BSE_DW08	BlueSphere	13	✓	✓
BSE_DW11	BlueSphere	9.5	✓	x
BSE_DW12	BlueSphere	12	✓	✓
BSE_DW15	BlueSphere	9	✓	✓
BSE_DW16	BlueSphere	11.5	✓	x
MW_EPA10A	Fyfe	15	✓	x
MW_EPA11	Fyfe	20	✓	x
MW_EPA12	Fyfe	16.2	✓	x
MW_EPA14	Fyfe	14.5	✓	x
MW_EPA15	Fyfe	12	✓	x
MW_EPA19	Fyfe	20	✓	x
MW_EPA26	Fyfe	10.5	✓	✓

Table 8 Geophysical Logging Schedule

Bore ID	Installed by	Depth (m)	Gamma Logging	Induction Logging
MW_EPA30	Fyfe	13	✓	x
MW_EPA31	Fyfe	13.6	✓	x
MW_EPA32	Fyfe	13.5	✓	x
Off-Site - Tonsley				
MW_EPA2	Fyfe	15.8	✓	x
W6	URS	17.7	✓	x
GW45_URS	URS	20.7	✓	✓
On-Site – Section 14				
MWS11_01	PB	15	✓	x
BSE_GW01	BlueSphere	14	✓	✓
TOTAL			23	7

6 Methodology

6.1 Groundwater

6.1.1 Groundwater Gauging

Prior to commencing sampling, on-site and off-site groundwater monitoring wells were gauged in a single gauging event (undertaken over three consecutive days on 29 and 30 November 2017 and 1 December 2017). Gauging was undertaken with an interface meter to enable the detection of NAPL (both light and dense), should it be present. Calibration certificates for the interface probe are included in **Appendix D**.

6.1.2 Groundwater Sampling

On-site and off-site groundwater monitoring wells were sampled using a low-flow sampling methodology consistent with the South Australian EPA Guidelines (SA EPA, 2007). The following sampling protocols were observed:

- Field parameters including pH, electrical conductivity, dissolved oxygen, redox potential and temperature were measured continuously, with at least the final three readings recorded to demonstrate stabilisation of the parameters as defined in SA EPA (2007). Calibration certificates for the water quality meter are included in **Appendix D**;
- Minimum purge volume prior to sampling was 2 litres, where possible;
- For low-flow sampling, maximum water column draw-down was limited to 0.1 m. If draw-down exceeded 0.1 m at a pump rate of less than 30 mL/min, then the well was purged, left to recover and sampled within 24 hours;
- Dedicated LDPE tubing, bladders and filtration equipment were utilised. All other sampling equipment was decontaminated between each location using dilute Decon 90 solution and a two rinse system. The decontamination procedure was subject to a QA/QC assessment through the analysis of rinsate samples taken at a rate of one per day per piece of sampling equipment; and
- Groundwater samples (including QA/QC samples) were collected from each groundwater monitoring well, using laboratory supplied bottles preserved appropriately and submitted to the laboratory in ice-chilled eskies under chain of custody procedures for the required analysis within the permitted sample holding time.

A specialist contractor was engaged to provide traffic management services where the locations of monitoring wells (in roadways) required traffic management for safe access.

6.1.3 Groundwater Analysis

Samples were sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis under the chain of custody procedures. Australian Laboratory Services (ALS) was used for analysis of primary samples and Envirolab Group (Envirolab) for analysis of inter-laboratory field duplicates.

All groundwater samples were analysed for VCH with selected samples also analysed for TRH fractions, BTEX compounds and bio-attenuation indicators. A full analytical schedule is provided in **Table 4** and **Table 5**.

6.2 Soil Vapour

6.2.1 Soil Vapour Bore Installation

The soil vapour monitoring bore installation program was conducted in accordance with the following methodologies:

- A site inspection prior was conducted prior to the commencement of drilling works for service clearance by an accredited service locator in accordance with BlueSphere's Underground Service Clearance Procedure;
- A pre-drilling protocol involving hand auguring to 1m depth was used prior to mechanical drilling to help avoid damage to services and confirm safe ground conditions;
- Following hand auguring, the vapour monitoring bores were drilled to the required depth using a direct push tube method to enable accurate logging of the undisturbed soil core;
- The three separate depth bores at each location (nested bores) were installed in separate boreholes drilled at least 1 m apart;
- The locations of the soil vapour bores were recorded using a hand-help GPS accurate to better than $\pm 1\text{m}$;
- The soil profile was logged in accordance with relevant Australian Standards and included detailed descriptions of the materials encountered including (where applicable) colour, grain size, mineralogical composition, rock type, roundness and sphericity, degree of weathering and any observations of staining/discholoration or odour;
- Soil samples were not collected for chemical analysis (as this is outside the current scope of work);
- Soil vapour wells were installed using 150mm screened mesh soil vapour implants connected to the surface with Teflon tubing. A gravel pack layer, approximately 400 mm thick was placed around the screen and the bores were sealed above the gravel pack to the surface. The wells were capped using "swagelok" connectors; and
- Soil vapour bores were completed with a metal gatic cover.

The soil vapour bore construction logs including the GPS survey coordinates for the wells are attached as **Appendix E**.

6.2.2 Soil Vapour Sampling

Soil vapour sampling was conducted in accordance with guidance provided in the ASC NEPM (Schedule B2) and referenced guidance documents including:

- Davis, GB, Patterson, BM & Trefry, MG. 2009. Field Assessment of vapours, CRC CARE Technical report no. 13;
- NSW EPA, 2012. Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases, November 2012; and
- CRC CARE 2013, Petroleum hydrocarbon vapour intrusion assessment: Australian guidance. CRC CARE Technical report No. 23.

The soil vapour bores were sampled according to the following procedure:

- Prior to sampling, the above ground sampling train was leak tested by conducting a shut-in test to ensure that the sampling train maintained an applied vacuum. This involved isolating the sampling train from the soil vapour probe and the collection canister before applying a vacuum of approximately 6 inches of mercury ("Hg) to the sampling train by withdrawing a plastic syringe barrel. A satisfactory seal for the sampling train is indicated if the pressure gauge maintains the applied pressure for a period of 30 seconds.
- Prior to sampling the soil vapour bore were leak tested by enclosing the top of the bore with a shroud and flooding it with 97% helium. The helium concentration in the shroud was tested with a helium meter, before the helium concentration in soil vapour from the probe was measured with the same device to ensure that unacceptable concentrations of helium are not present in the soil vapour sample from connection to the surface. An unacceptable concentration of helium is defined as greater than 10% of the helium concentration within the shroud at the top of the bore.

- Three dead volumes from the implant, tube and sand pack was then be purged from the bore using an LFG meter. The concentrations of oxygen, methane and carbon dioxide in the purged gas was recorded to ensure they have stabilised. The soil vapour was also screened for the presence of Volatile Organic Compounds (VOCs) using a photo ionisation detector (PID).
- The soil vapour probe was then collected into laboratory supplied 1.4 litre mini-cans evacuated to approximately 30 inches of mercury (“Hg). Generally, 60 ml/min flow regulators were used to fill the canisters, although at some locations with particularly tight formations, 12 ml/min flow regulators were used to prevent creation of excessive vacuum in the wells and possible stripping of volatiles from soil and groundwater. Canister and regulator verification reports are provided as **Appendix F**.
- Once the pressure in the mini-can had fallen to approximately 5 “Hg sampling was stopped, the mini-can sealed, and the pressure recorded prior to packaging and transhipment to the laboratory under Chain of Custody procedures.
- The pressure within the well was monitored during sampling. Where the vacuum in the bore exceeded 7 “Hg, a note was made on the field sampling sheet. Where the pressure in the bore continues to rise above about 12 “Hg sampling was abandoned.
- Relevant data including sampler’s name, sampling commencement and finish times, canister pressures, field measurements, temperature, humidity and atmospheric pressure was recorded on field data sheets at the time of sampling.
- Intra-laboratory duplicate samples and inter-laboratory triplicate samples were collected at a rate of one for every 20 primary samples. Where possible duplicate samples were collected simultaneously with collection of the primary samples by splitting the sample stream using a “Y” piece.
- Non-dedicated components of the sampling train were thoroughly purged in air between bores, and where possible bores were sampled from less contaminated bores to more contaminated bores to minimise the potential for cross-contamination between bores.
- Samples were sent to a National Association of Testing Authorities (NATA) accredited laboratory, under similar chain of custody procedures as those described for groundwater samples. Australian Laboratory Services (ALS) was used for analysis of primary samples and Envirolab Group (Envirolab) for analysis of inter-laboratory field triplicates.

A specialist contractor was engaged to provide traffic management services where the locations of soil vapour bores (in roadways) require traffic management for safe access.

6.2.3 Soil Vapour Analysis

Soil vapour samples were sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis. For the first round of sampling Australian Laboratory Services (ALS) was used for analysis of primary samples and Envirolab Group (Envirolab) for analysis of inter-laboratory field triplicates. For the second round of sampling Eurofins MGT was used for primary samples and Envirolab for analysis of inter-laboratory field triplicates. All soil vapour samples were analysed for VCH using US EPA Method TO-15. Selected on-site samples were also analysed for TRH fractions and BTEX compounds. The full analytical schedule is presented on **Table 6** and **Table 7**.

6.3 Down-Hole Geophysical Logging

Geophysical borehole logging was undertaken in 23 existing groundwater monitoring wells using a natural gamma probe (NGRS). The gamma probe measured naturally occurring radioactivity such as K^{40} , Th^{232} , and $U^{232-238}$, each of these isotopes are associated with certain rocks and sediments, enabling the lithology to be identified.

In addition to the gamma probe, an induction (conductivity) probe was used in seven of the key groundwater monitoring wells. The induction probe provided complementary evidence to assist in identifying relatively high or low conductivity lenses within the selected wells.

A specialist contractor (Borehole Wireline) was engaged to conduct the geophysical logging. BlueSphere has previously engaged Borehole Wireline to undertake a similar geophysical logging program at 22 on-Site and 16 off-Site groundwater monitoring wells in 2015 (BlueSphere, 2016a). The logging was conducted as follows:

- The probe was lowered to the base of the groundwater monitoring well and then the geophysical data was collected in an upwards logging direction as the probe was raised to the surface.
- A data acquisition rate of 2.5 m/min was used based on advice from Borehole Wireline that no additional resolution would be achieved by using a slower acquisition rate;
- The probe and cable were decontaminated between each location using a phosphate free solution and rinse system; and
- The geophysical logging data was compiled into composite logs. A volume of clay (VCL) curve calculation was also derived from the gamma curve for each well.

The groundwater monitoring wells selected for gamma logging are shown on **Figure F8**. The majority of the groundwater monitoring wells were selected to provide information along the main axes of the off-Site plume as well as providing some lateral transects across the plume where it narrows towards its down-gradient extent to the north of Alawoona Avenue. Some additional groundwater monitoring wells were selected within the Relocation Area to the south of the MMAL site, and within Section 14 of the MMAL site to provide additional information on the saturated zone geology in these areas.

Two of the monitoring wells logged in 2015 (MW_EPA10A and MW_EPA19) were selected for re-logging to enable comparison of the new data with that obtained in 2015.

7 Adopted Assessment Criteria

7.1 Groundwater

The primary source of water quality guidelines is the Environment Protection (Water Quality) Policy 2003 (EPP)¹. The EPP provides water quality criteria for chemicals in particular water body types for marine water, inland surface waters and groundwater. The relevant protected environmental values include:

- Freshwater Aquatic Ecosystems;
- Primary Contact Recreation and Aesthetics;
- Potable Water;
- Agriculture/Aquaculture; and
- Industrial uses.

Application of the appropriate criteria requires a Beneficial Use Assessment conducted in accordance with the SA EPA *Guidelines for the Assessment and Remediation of Groundwater Contamination* (2009) to determine the appropriate environmental values of groundwater to be protected.

Where there are no assigned criteria concentrations in the EPP (as is the case for TCE), concentrations reported above the laboratories limit of reporting are used for the purpose of identifying whether a Section 83A Notification is required.

Subsequent assessment of the potential risks to identified environmental values from groundwater contamination is guided by the SA EPA publications: *Guidelines for the Assessment and Remediation of Groundwater Contamination* (2009); and *Site Contamination: How to determine actual or potential harm to water that is not trivial* (2008).

In the absence of EPP criteria, Tier 1 screening levels will be obtained from the following sources:

- ASC NEPM Groundwater Investigation Levels (GILs);
- Australian Water Quality Criteria (ANZECC, 2000);
- Australian Drinking Water Guidelines (NHMRC & ARMCANZ, 2011);
- Guidelines for Managing Risks in Recreational Waters (NHMRC, 2008);
- World Health Organisation (WHO) drinking water guidelines (4th edition, 2011); and
- US EPA Regional Screening Levels (RSLs, January 2015).

Where the site contaminants of concern are not sufficiently addressed within the ASC NEPM, then alternative guidelines are proposed. In some risk exposure pathways, the adopted criteria may subsequently be superseded by site-specific target levels (SSTLs) calculated from future detailed site specific risk assessment (SSRA).

For the purposes of delineation of the off-site VCH plume, the plume was contoured to a minimum concentration of 5 µg/L TCE. This is consistent with the approach previously adopted by the EPA for the work conducted in Mitchell Park by Fyfe in 2014 (Fyfe, 2014), and for more recent investigations commissioned by the EPA at Beverley. This concentration is 25% of the WHO drinking water quality guideline of 20 µg/L (WHO, 2011) and represents a reasonable level at which

¹ The EPA advised (23 December 2015) that water quality criteria in the Water Quality Policy 2003 for protected environmental values will continue to be used for the purpose of determining site contamination that affects or threatens underground water under section 83A of the Environment Protection Act 1993.

the risks to residents can be considered to be negligible given that the groundwater is not suitable for potable use.

For the purpose of determining site contamination that affects or threatens underground water under section 83A of the *Environment Protection Act 1993* (EP Act), where there are no assigned criteria concentrations in the Environment Protection Policy (Water Quality) EPP (2003) (as is the case for TCE), concentrations reported above the limit of reporting (LOR) (lowest detection limit defined as ultra-trace for VCH) will be applied.

VCH are not naturally occurring compounds and as such are assumed to have no natural or regional background concentration. While the background concentrations should be zero, for practical purposes the background concentrations for VCH are assumed to be equal to the laboratory limit of reporting (LOR) for each compound using the most sensitive (ultra-trace) analytical method.

7.2 Soil Vapour

7.2.1 Tier 1 Criteria

Analysis of soil vapour results was compared against published Tier 1 criteria. Relevant Tier 1 soil vapour investigation and screening levels outlined in the ASC NEPM include:

- Interim soil vapour health investigation levels (HILs) for volatile organic chlorinated compounds; and
- Health screening levels (HSLs) for petroleum hydrocarbons.

Soil vapour HILs and HSLs are provided for Residential A, Residential B, Recreational C and Commercial/Industrial D settings. Confirmed exceedances of the Tier 1 criteria indicate the need for a site-specific risk assessment. HILs for the Residential A setting were adopted for off-site investigation areas (outside the former MMAL site) within Tonsley and Mitchell Park. As there is no evidence of MMAL site-related petroleum hydrocarbon impacts in the off-site areas, soil vapour samples from off-site areas were not analysed for petroleum hydrocarbons and were therefore not assessed against HSLs for petroleum hydrocarbons.

HILs and HSLs for the Commercial/Industrial D setting were adopted for investigation locations within the former MMAL site (noting that no investigations have been conducted within the Residential Audit Area).

Selection of HSLs for petroleum hydrocarbons requires the appropriate soil type and measurement depth to be identified. In selecting Tier 1 screening criteria for this report the most conservative values (i.e. sandy soils at a depth of 1 to 2 m bgl) were adopted (noting that all soil vapour samples were collected from a depth of at least 1.5 m bgl).

A Tier 1 screening criterion for trans-1,2-DCE vapours could not be found, consequently the HIL for cis-1,2-DCE was adopted for the sum of cis and trans-1,2-DCE, noting that the ASC NEPM (Schedule B7, Appendix A6) states that "cis-1,2-DCE is considered to be more toxic than trans-1,2-DCE and hence the HILs derived for the cis-isomer are adequately protective of exposures associated with the trans isomer".

No Tier 1 screening criterion is available for 1,1-DCE. A preliminary Tier 1 screening level has been calculated for 1,1-DCE using the methodology applied in the ASC NEPM to calculate the interim soil vapour HILs for volatile organic chlorinated compounds. This involves identifying a reference concentration (RfC) or screening level that represents a safe exposure level in indoor air (for residential or commercial/ industrial settings) and applying a soil vapour to indoor air attenuation factor of 0.1 to generate a preliminary Tier 1 soil vapour screening criterion. It is noted that due to the absence of relevant data, no allowance for background intake has been made in calculating this preliminary Tier 1 screening criteria.

A screening level for indoor air has been obtained from the US EPA Risk Based Screening Tables (<http://www.epa.gov/risk/risk-based-screening-table-generic-tables>). The indoor air screening level corresponding to a Hazard Index of 1 has been adopted and the soil vapour to indoor air

attenuation factor of 0.1 was then applied to generate the preliminary Tier 1 soil vapour screening criteria.

HILs and HSLs adopted for this investigation are presented in **Table 9** below.

Table 9 Adopted Soil Vapour HILs and HSLs

VOC	Interim Soil Vapour HIL or HSL ($\mu\text{g}/\text{m}^3$)	
	Residential	Commercial/ Industrial
PCE	2,000	8,000
TCE	20	80
1,1-DCE	2,100*	8,800*
Sum of cis and trans-1,2-DCE	80**	300**
VC	30	100
Benzene	na	10,000
Toluene	na	16,000,000
Ethylbenzene	na	4,600,00
Xylenes	na	3,200,000
Naphthalene	na	15,000

Notes: * HILs for 1,1-DCE calculated from US EPA Risk Based Screening Levels

** HILs for cis-1,2-DCE have been adopted for the sum of cis and trans-1,2-DCE.

na = not applicable

7.2.2 Tier 2 Site Specific Residential Criteria for TCE

In 2014 SA EPA and SA Health developed a series of TCE indoor air quality response levels applicable to the residential properties within Mitchell Park and Clovelly Park. A summary of these indoor air quality response levels is shown in **Table 10** below:

Table 10 Tier 2 TCE Indoor Air Criteria

TCE Indoor Air Concentration ($\mu\text{g}/\text{m}^3$)	Health Risk	Site-Specific Actions
<LOR	Safe	None
<2	Safe	None
2 - <20	No immediate health concerns	Further assessment necessary
20 - <200	There may be a health risk	Intervention: immediately look at next steps and further assessment
200 and greater	There is a health risk	Accelerated intervention: Immediate action (relocation or mitigation)

These response levels are not directly applicable to this investigation as they apply to indoor air concentrations and this investigation is limited to soil vapour sampling.

It is noted that BlueSphere (2017a) has previously derived soil vapour to indoor air attenuation factors to relate measured soil vapour and groundwater concentrations to predicted indoor air concentration.

8 Data Validation

8.1 Introduction

Analytical data validation is the process of assessing if data are in compliance with method requirements and project specifications. The primary objectives of this process are to ensure that data of known quality are reported, and to identify if the data can be used to fulfil the overall project objectives.

8.2 Groundwater Data

The field sampling was conducted according to standard industry Quality Assurance/Quality Control (QA/QC) procedures. Samples were transported under chain of custody (COC) protocols with instructions for analysis to BlueSphere's nominated laboratories. ALS was used as the primary laboratory and Envirolab as the secondary laboratory. Both laboratories are NATA accredited for the requested analyses.

Intra-laboratory duplicate samples and inter-laboratory samples were collected to provide at least one duplicate and triplicate sample for each twenty (20) primary samples.

An equipment rinsate blank was collected on daily basis and trip blanks collected and analysed for each sample transport container (insulated cooler).

BlueSphere conducted comprehensive QA/QC assessments of the first round of groundwater sampling data collected between 15 January 2018 and 21 January 2018, and the second round collected between 16 April 2018 and 23 April 2018. Data validation reports for the first and second round of groundwater sampling are provided in **Appendix G**.

Specific elements of data validation that were checked and assessed for this project included:

- Sample holding times;
- Temperature of samples upon arrival at laboratory;
- Frequency of conducting quality control measurements;
- Intra laboratory relative percentage differences;
- Internal laboratory QA/QC data;
- Required reporting limits; and
- The occurrence of apparently unusual or anomalous results (e.g. laboratory results that appear to be inconsistent with field observations or measurements).

A small number of minor exceedances of the acceptability criteria are noted in **Appendix G**. However, these issues were not considered to significantly compromise the overall quality of the data and BlueSphere considers the groundwater analytical data to be of a suitable precision and accuracy to meet the data quality objectives.

8.3 Soil Vapour Data

The soil vapour sampling conducted was conducted according to standard industry QA/QC procedures. Samples were transported under Chain of Custody protocols with instructions for analysis to BlueSphere's nominated laboratories. For the first round of soil vapour sampling ALS was used as the primary laboratory and Envirolab as the secondary laboratory. For the second round Eurofins MGT was used as the primary laboratory and Envirolab as the secondary laboratory. All three laboratories are NATA accredited for the requested analyses.

Intra-laboratory duplicate samples and inter-laboratory samples were collected to provide at least one duplicate and triplicate sample for each twenty (20) primary samples.

BlueSphere conducted comprehensive QA/QC assessments of the data collected for first round of soil vapor sampling conducted between 6 November 2017 and 27 November 2017, and the second round conducted between 26 March 2018 and 29 March 2018. Data validation reports for the first and second round of soil vapour sampling are provided in **Appendix H**.

Specific elements of data validation that were checked and assessed for this project are:

- Sample holding times;
- Canister pressure on sample collection and arrival at laboratory;
- Frequency of conducting quality control measurements;
- Intra and inter laboratory relative percentage differences;
- Internal laboratory QA/QC data;
- Required reporting limits; and
- The occurrence of apparently unusual or anomalous results (e.g. laboratory results that appear to be inconsistent with field observations or measurements).

It is noted that anomalously high PCE concentrations were reported by the primary laboratory (Eurofins MGT) at three locations during the second round of soil vapour sampling. At one of these locations an inter-laboratory triplicate analysis conducted by Envirolab did not support the high concentration reported by Eurofins MGT. Consequently, it is considered that caution should be exercised in interpreting high PCE values reported by MGT Eurofins that are not reflective of historical data. It is noted, however, that PCE is not a primary risk driver for the site and the discrepancies noted are unlikely to affect the interpretation of the data.

In summary, the soil vapour analytical data obtained for this report was deemed to be acceptable for interpretive use based on the data quality assurance and control (QA/QC) assessment completed.

9 Groundwater Investigation Results

9.1 Groundwater Gauging

Data from the groundwater gauging round conducted on 29 November 2017, 30 November 2017 and 1 December 2017 is presented in **Table T1**. A figure showing the inferred groundwater contours and flow directions is attached as **Figure F11**. Field sheets are presented as **Appendix I**. The inferred groundwater contours are generally consistent with those obtained from previous gauging rounds (**Figure F9** and **Figure F10**) and show the groundwater flow direction across the former MMAL site is broadly in a west to north-westerly direction, with the flow direction swinging more to the north-west down-gradient of the MMAL site in Mitchell Park and Marion. It is noted that particularly steep groundwater gradients (as indicated by tightly spaced contour lines) are present in the vicinity of the former R&C site and near the south-western corner of the MMAL site. No NAPL was identified at any of the gauged wells.

A substantial rise in reduced water levels relative to the previous monitoring round conducted in September 2016 was seen in the off-site wells to the west of the MMAL site. The magnitude of this rise varied from approximately 0.3 to 0.5 m in Mitchell Park close to the MMAL site boundary to approximately 1 m in the north-west of the study area (i.e. near the down-gradient extent of the VCH plume).

The observed changes in reduced water level were more variable within the MMAL site, with a slight fall in water levels (of the order of 0.1 m) generally seen in the vicinity of EPA Designated Source Area 4, and a substantial rise of the order of 1 to 2 m seen at a number of locations in the vicinity of EPA Designated Source Area 3.

9.2 Round 1 Groundwater Sampling – January / February 2018

9.2.1 On-Site Groundwater Wells

Groundwater sampling field parameters are presented in **Table T2**. The first round of on-site groundwater contaminant concentration data is presented in **Table T3**. Historical data for the sampled wells is presented in **Table T4**. Field sheets are presented as **Appendix J** and the laboratory certificates are presented as **Appendix L**.

9.2.1.1 Contaminant Distribution

Summaries of the new and historical groundwater data for the sampled on-site groundwater monitoring wells are provided on **Figure F14** to **Figure F16**. The distribution of VCH contaminants within the uppermost Quaternary aquifer is broadly consistent with previous data, with the highest VCH concentrations seen in the south-western corner of the MMAL site within EPA Designated Source Area 3. Other regions of elevated VCH concentrations are found within Section 14 south of the TAFE building, in a band running from beneath the TAFE building into the southern end of EPA Designated Source Area 4, and across the northern part of EPA Designated Source Area 4.

Examination of the TRH and BTEX data obtained from selected on-site wells shows a trace of TRH (C₁₆-C₃₄ fraction) (140 µg/L) was reported in monitoring well BSE_GW10 in February 2018 (Round 1). A trace of TRH (C₁₆-C₃₄ fraction) (220 µg/L) was also reported for well GW43_URS which is located near the MMAL / Monroe boundary. Gross petroleum hydrocarbon contamination was not seen in any of the on-site wells monitored in February 2018. TRH (C₆-C₁₀) fraction was noted in a number of groundwater wells, but in each case is likely to be related to chlorinated hydrocarbons rather than the petroleum hydrocarbons.

Petroleum hydrocarbon biodegradation indicators (sulphate, nitrate, ferrous iron, dissolved manganese and dissolved methane) were analysed for samples from eight groundwater monitoring wells (BSE_GW01 to BSE_GW 05, GW41_URS, GW43_URS and MWS11_01). The results for these analytes in conjunction with field measurements of dissolved oxygen (DO), redox potential and electrical conductivity (EC) are presented in **Table 11**.

Table 11 Biodegradation Indicators

Well ID	Fe ²⁺ (mg/L)	Mn ⁴⁺ (mg/L)	CH ₄ (mg/L)	NO ₃ ⁻ (mg/L-N)	SO ₄ ²⁻ (mg/L-S)	DO * (mg/L)	Redox (mV)	EC (µS/cm)
BSE_GW01	<0.05	<0.001	<0.01	1.5	143	4.8	128	2,647
BSE_GW02	<0.05	0.002	<0.01	12.3	148	4.1	101	3,001
BSE_GW03	<0.05	0.002	<0.01	11.5	217	3.9	110	4,120
BSE_GW04	<0.05	0.001	<0.01	7.38	137	2.8	115	4,252
BSE_GW05	<0.05	<0.001	<0.01	11.8	90	3.0	114	1,227
GW41_URS	<0.05	0.002	<0.01	2.62	312	Insufficient water		
GW43_URS	<0.05	<0.001	<0.01	0.97	224	4.5	117	4,599
MWS11_01	<0.05	0.005	<0.01	4.55	268	2.2	99	5,472

Notes: *.Redox potentials are presented uncorrected, relative to a saturated KCl reference electrode.

The field data indicates that the groundwater is well oxygenated and reporting redox potentials indicative of oxidising conditions at all locations, suggesting that reductive dechlorination of TCE is unlikely to be occurring at substantial rates at any of these locations.

The laboratory data provides no strong indications of active hydrocarbon biodegradation, although it is possible that low nitrate concentrations at wells BSE_GW01, GW41_URS, GW43_URS and MWS11_01 may indicate that some hydrocarbon degradation has occurred at these locations via denitrification. It is noted that these four wells are all located in the eastern section of Section 14 where previous monitoring (BlueSphere, 2016a) has indicated the presence of low concentrations of TRH in the C₁₀⁺ fraction.

9.2.1.2 Concentration Stability Assessment

The criteria for demonstrating groundwater contaminant concentration stability (for TCE and total VCH concentrations) outlined in **Section 4.5** were applied to determine which groundwater wells can be considered stable and well characterised, and which bores require further sampling as part of the second round of sampling. A spreadsheet showing the stability calculations is attached as **Appendix N**.

Thirteen of the 31 sampled on-site groundwater monitoring wells met the stability criteria and were therefore considered to be adequately characterised.

The following points are noted with respect to the other groundwater wells:

- Eleven wells (BSE_GW01, BSE_GW03 to BSE_GW07, BSE_GW09, BSE_GW10, MWS17_01A, MWS17_06, MWS17_07) had only been sampled twice, and thus required a third round of sampling;
- Two wells (BSE_GW02, MWS18_02A) failed the stability criteria;
- Four wells (GW42_URS, GW43_URS, GW44_URS and MWS11_03) showed a potentially significant increasing trend; and
- One well (MWS11_01) was analysed out of holding time.

It was therefore considered that the 18 groundwater wells listed above were required for inclusion in the second round of sampling.

9.2.2 Off-Site Groundwater Wells

The first round of off-site groundwater contaminant concentration data is presented in **Table T5**. Historical data for the sampled wells is presented in **Table T6**. Groundwater sampling field parameters are presented on **Table T2**. Field sheets are presented as **Appendix J** and the laboratory certificates are presented as **Appendix L**.

9.2.2.1 Contaminant Distribution

Summaries of the new and historical groundwater data for the sampled off-site groundwater monitoring wells are provided on **Figure F17** to **Figure F19**. Comparison of the off-site groundwater VCH contaminant data with previous data shows a high degree of stability. Inferred groundwater TCE concentration contours for off-site wells to the west of the MMAL site are presented as **Figure F20**. Consistent with the previous data the following key points are noted with respect to the extent of the off-site VCH impacts in groundwater:

- A region of high VCH (predominantly TCE) concentrations in groundwater (ranging between 1,000 – 9,999 µg/L) is present immediately west of EPA Designated Source Area 3 in the south-west corner of the MMAL site;
- A region of moderately elevated TCE concentrations in groundwater (ranging between 100 – 999 µg/L) is present immediately west of EPA Designated Source Area 4;
- A small area of elevated 1,1-DCE concentrations is present immediately west of the MMAL site between EPA Designated Source Areas 3 and 4;
- Low groundwater VCH concentrations (<100 µg/L) are present along the line of Bradley Grove approximately 120 m west of the MMAL site boundary, running in a north south orientation; and
- Higher TCE concentrations in groundwater are present in wells MW_EPA29 and MW_EPA22 approximately 100 to 150 m west of Bradley Grove, with a continuous plume extending approximately 1.3 km north-north-west of these monitoring wells.

9.2.2.2 Concentration Stability Assessment

The criteria for demonstrating groundwater contaminant concentration stability (for TCE and total VCH concentrations) outlined in **Section 4.5** were applied to determine which groundwater wells can be considered stable and well characterised, and which bores require further sampling as part of the second round of sampling. A spreadsheet showing the stability calculations is attached as **Appendix N**.

Twenty-four of the 41 sampled off-site groundwater monitoring wells met the stability criteria and were therefore considered to be adequately characterised.

The following points are noted with respect to the groundwater wells:

- Two wells (MW_EPA29 and GW1) failed the stability criteria;
- Seven wells (BSE_DW02, BSE_DW03, MW_EPA2, MW_EPA10A, MW_EPA11, MW_EPA12 and MW_EPA13) showed a possible increasing trend in TCE concentration;
- Seven wells (BSE_DW11 to BSE_DW 15 ,BSE_DW17 and BSE_DW18) have only been sampled twice;
- Well BSE_DW16 has only been sampled once as it was covered with construction waste in November 2017 and could not be sampled. The construction waste was subsequently removed; and
- Well BSE_DW10 is lost.

On the basis of this data, it was determined that seventeen groundwater monitoring wells should be resampled in the second round of sampling:

- Seven wells (BSE_DW11 to BSE_DW15, BSE_DW17 and BSE_DW 18) that have only been sampled twice;

- Two wells (MW_EPA29 and GW1) that failed the stability criteria;
- Seven wells (BSE_DW02, BSE_DW03, MW_EPA2, MW_EPA10A, MW_EPA11, MW_EPA12 and MW_EPA13) that showed a possible increasing trend in TCE concentration; and
- Well BSE_DW16 which was buried under construction waste in November 2017.

9.3 Round 2 Sampling – April 2018

9.3.1 On-Site Groundwater Wells

The second round of on-site groundwater contaminant concentration data is presented in **Table T3**. Historical data is presented in **Table T4**. Summaries of the VCH data are provided on **Figure F14** to **Figure F16**. Groundwater sampling field parameters are presented in **Table T2**. Field sheets are presented as **Appendix J** and the laboratory certificates are presented as **Appendix L**.

9.3.1.1 Concentration Stability Assessment

The additional data was incorporated into the stability calculation spreadsheet (**Appendix N**) to assess whether the VCH contaminant concentrations at the resampled wells could be considered as well characterised following the additional round of sampling.

The following key points are noted:

- The ten wells (BSE_GW01, BSE_GW03 to BSE_GW07, BSE_GW09, BSE_GW10, MWS17_06, MWS17_07) that had previously been sampled only twice, all satisfied the stability criteria after the additional round of sampling and can be considered adequately characterised;
- Monitoring well MWS18_02A which failed the stability criteria following the first round of sampling, met the criteria after the additional sampling round;
- Monitoring well BSE_GW02, located on the western boundary of EPA Designated Source Area 4, again failed the stability criteria and showed a potential increasing trend over the four monitoring rounds. It is noted that the reported TCE concentrations are relatively low (<100 µg/L) and that the off-site monitoring well MW_EPA16, located directly across the railway line from BSE_GW02 has reported stable VCH concentrations;
- Four wells (GW42_URS, GW43_URS, GW44_URS and MWS11_03) which showed a potential increasing trend following the first round of sampling, all reported lower concentrations in the second round of sampling, suggesting that an increasing trend was not present; and
- Monitoring well MWS11_01 which was analysed out of holding time during the first round was successfully resampled and met the stability criteria.

In summary, the results of the second round of on-site groundwater sampling support that the distribution of VCH contaminants in the uppermost Quaternary aquifer within the MMAL site is broadly stable. It is considered that the VCH concentrations in groundwater are well characterised for the selected on-site groundwater monitoring wells, according to the criteria set out in **Section 4.5**, with the exception of well BSE_GW02, which shows a possible increasing trend on a relatively low TCE concentration of <100 µg/L.

The data from the selected groundwater monitoring wells sampled as part of this investigation generally support the VCH concentration data collected from previous monitoring rounds. The data provides strong support that the interpreted uppermost Quaternary aquifer groundwater VCH concentration contour plans (BlueSphere, 2016a) (prepared from the more extensive groundwater monitoring round conducted in July to September 2015) provide a consistent representation of the distribution of VCH contaminants in the uppermost Quaternary aquifer across the southern half of the MMAL site.

9.3.2 Off-Site Groundwater Wells.

The second round of off-site groundwater contaminant concentration data is presented in **Table T5**. Historical data is presented in **Table T6**. Summaries of the VCH data are provided on **Figure F17** to **Figure F19**. Groundwater sampling field parameters are presented on **Table T2**. Field sheets are presented as **Appendix J** and the laboratory certificates are presented as **Appendix L**.

9.3.2.1 Concentration Stability Assessment

The additional data was incorporated into the stability calculation spreadsheet (**Appendix N**) to assess whether the VCH contaminant concentrations could be considered well characterised following the additional round of sampling.

The following key points are noted:

- The seven wells (BSE_DW11 to BSE_DW15, BSE_DW17 and BSE_DW 18) that had previously been sampled only twice, all satisfied the stability criteria after the additional round of sampling and can be considered adequately characterised;
- Monitoring well MW_EPA29, which previously failed the stability criteria following the first round of sampling could not be re-sampled as it contained insufficient water. It is noted that the reported TCE concentration in the first round of sampling was 154 µg/L, up from 84.4 µg/L in September 2016. Some uncertainty remains with regard to the VCH concentrations in groundwater at this location, although it is noted that the maximum reported TCE concentration (154 µg/L) is low relative to some other off-site locations;
- Monitoring well BSE_DW16 which could not be sampled in Round 1 was sampled in Round 2. The reported VCH concentration was low (<5 µg/L) and consistent with the September 2016 data. This well is therefore considered to be adequately characterised;
- The Round 2 sample from well GW1 (8 µg/L) returned a similar TCE concentrations to the Round 1 sample (10 µg/L), but this was much lower than the concentration reported in July 2012 (337 µg/L). Given the consistency between the two recent samples and the long period that has elapsed since the 2012 sample, this well is considered to be adequately characterised;
- Results of the Round 2 sampling did not support the possible increasing trends identified for wells MW_EPA11, MW_EPA12 and MW_EPA13;
- Results of the Round 2 sampling showed possible continuing increasing trends for wells BSE_DW02, MW_EPA2, and MW_EPA10A, although it is noted the increases are relatively modest in nature. The increases in TCE concentrations reported in these wells were as follows:
 - BSE_DW02 increased from 9.8 µg/L in September 2016 to 29 µg/L in April 2018;
 - MW_EPA2 increased from 993 µg/L in October 2014 to 1480 µg/L in April 2018; and
 - MW_EPA10A increased from 61 µg/L in October 2014 to 175 µg/L in April 2018.

In summary, the results of the second round of on-site groundwater sampling conducted in April 2018 support that the distribution of VCH contaminants within the uppermost Quaternary aquifer to the west and south of the MMAL site is broadly stable. There were no detections of VCH in groundwater monitoring wells where VCH had not been previously detected.

It is considered that the VCH concentrations in groundwater are well characterised for the majority of the off-site groundwater monitoring wells, according to the criteria set out in **Section 4.5**. The only exceptions include well MW_EPA29 (which could not be sampled in the second round), and possible increasing trends at wells BSE_DW02, MW_EPA2, and MW_EPA10A. However, it is noted that rates of increase seen in these wells are modest.

9.4 Summary of Groundwater Data

9.4.1 On-Site Data

Comparison of the VCH concentration data from the selected on-site groundwater wells against data from previous monitoring rounds in general shows a satisfactory degree of consistency.

On-site concentration contours have not been generated from the 2018 groundwater data as there are insufficient data points to produce a meaningful contour map from the February 2018 and April 2018 sampling rounds. However, the stability analysis suggests that the on-site VCH concentration contours generated from the data collected by BlueSphere in 2015 (BlueSphere, 2016a) provide a reliable picture of the distribution of VCH contaminants within the uppermost Quaternary aquifer across the southern half of the MMAL site. The TCE concentration contour map constructed from this data is included as **Figure F12**. Contour maps for other VCH contaminants are provided in **Appendix B**.

It should be noted that no groundwater sampling was conducted in the northern half of the MMAL site or on the Monroe site as part of these investigations, so no assessment can be made of the reliability of the 2015 VCH concentration contours in these areas.

9.4.2 Off-Site Data

An interpreted groundwater TCE concentration contour plan for off-site wells to the west of the MMAL site (for the uppermost Quaternary aquifer) constructed from data collected January 2018 is presented as **Figure F20**. As discussed in **Section 7.1**, the plan has been contoured to a minimum concentration of 5 µg/L (25% of the WHO drinking water guideline for TCE) which is considered to represent a reasonable level at which the risks to residents can be considered to be negligible given that the groundwater is not suitable for potable use. **Figure F20** shows that the plume is well delineated to the 5 µg/L level.

Comparison of **Figure F20** with off-site component of **Figure F12** (generated from data collected in September 2016) shows that the extent of the plume inferred from the two data sets are very similar. This provides confidence that the off-site uppermost Quaternary aquifer groundwater VCH plume is broadly stable, the extent of the plume is well characterised, and groundwater conditions within the off-site monitoring wells is well characterised.

10 Soil Vapour Investigation Results

10.1 Round 1- November 2017

10.1.1 On-Site Soil Vapour Bores

The soil vapour data for the newly installed 3-level soil vapour bores (BSE_SV01 to BSE_SV05) and the 13 existing on-site soil vapour bores that were sampled in the first round of sampling is presented in **Table T7**. Historical data for the sampled bores is presented in **Table T8**. Field sheets are presented as **Appendix K** and the laboratory certificates are presented as **Appendix M**. The reported soil vapour concentrations were broadly consistent with the previous data.

10.1.1.1 Contaminant Distribution

Soil Vapour Bores Installed in November 2017

Summaries of the soil vapour VCH data for the new on-site soil vapour bores are provided on **Figure F21** to **Figure F23**. Low TCE soil vapour concentrations ($<20 \mu\text{g}/\text{m}^3$) were reported in the BSE_SV01 series, located in the north-east corner of EPA Designated Source Area 4) and the BSE_SV03 series (located near the southern boundary of EPA Designated Source Area 4). All other VCH species were reported as <LOR.

Higher TCE concentrations in soil vapour were reported at depth in the BSE_SV02 series located in the north-western quadrant of EPA Designated Source Area 4. A TCE concentration of $5,060 \mu\text{g}/\text{m}^3$ was reported at a depth of 8 m. However, the TCE concentration at 2 m was only $12.9 \mu\text{g}/\text{m}^3$. All other VCH species were reported as <LOR.

Two sets of soil vapour bores (BSE_SV04 and BSE_SV05 series) were installed and sampled in EPA Designated Source Area 3. At BSE_SV04, located near the western boundary, all VCH concentrations were reported as <LOR. At the BSE_SV05 series, located near the centre of EPA Designated Source Area 3, moderate VCH concentrations were reported at depth, with the 8 m borehole reporting a TCE concentration of $3,900 \mu\text{g}/\text{m}^3$ and cis-1,2-DCE at $578 \mu\text{g}/\text{m}^3$. However, only $13.4 \mu\text{g}/\text{m}^3$ of TCE was reported in soil vapour from the shallow (2 m) bore.

Existing Soil Vapour Bores

Summaries of the new and historical soil vapour VCH data for the existing on-site soil vapour bores are provided on **Figure F21** to **Figure F23**. The figures show that, consistent with the historical data, particularly high soil vapour VCH concentrations are present near the boundary between the MMAL site and Relocation Area in the south-western corner of the MMAL site in the vicinity of soil vapour bores SV_EPA64, SV13 and SV31. Much lower soil vapour VCH concentrations were reported in bores sampled from the northern, western and central parts of EPA Designated Source Area 3.

10.1.1.2 Concentration Stability Assessment

The criteria for demonstrating soil vapour concentration stability (for TCE, 1,1_DCE and total VCH concentrations) outlined in **Section 4.5** were applied to determine which soil vapour bores can be considered stable and well characterised, and which bores should be sampled in the second round of sampling. A spreadsheet showing the stability calculations is attached as **Appendix O**.

The following points are noted with respect to the stability and degree of characterisation of the sampled bores:

- Seven bores (SV02, SV06, SV13_2M, SV13_6M, SV31, SV_EPA60A, SV07) were identified as being adequately characterised;
- The fifteen newly installed bores (BSE_SV01 to BSE_SV05 series) have only been sampled once;

- Five bores (SV01, SV_EPA62A, SV_EPA66, SV13_1M, SV13_4M) failed the stability criteria; and
- The SV_EPA64 series bores could not be located at the time of sampling but were subsequently located (SV1000 was sampled as a contingency).

On the basis of this data, it was considered that the following soil vapour bores should be resampled in the second round of sampling:

- Bore SV01, SV_EPA62A and SV_EPA66) which failed the stability criteria, plus the four SV13 bores (1 m, 2 m, 4 m and 8 m) of which two passed and two failed the stability criteria;
- The three SV_EPA64 series bores that could not be located at the time of the first round of sampling; and
- The five sets of newly installed soil vapour bores (BSE_SV01 to BSE_SV05 series) that had only been sampled once.

10.1.2 Off-Site Soil Vapour Bores

The Round 1 off-site soil vapour data is presented in **Table T9**. Historical data for the sampled bores is presented on **Table T10**. Field sheets are presented as **Appendix K** and the laboratory certificates are presented as **Appendix M**. The soil vapour contaminant concentration data generally showed a high degree of stability.

10.1.2.1 Contaminant Distribution

Summaries of the new and historical off-site soil vapour VCH data are presented on **Figure F24** to **Figure F27**.

The following points are noted with respect to the distribution of VCH contaminants in soil vapour in the area to the west of the MMAL site:

- The highest TCE concentrations in shallow (2 m) soil vapour were reported in soil vapour bores SV_EPA33A (1,200 µg/m³) and SV_EPA34A (698 µg/m³) located at the northern and southern ends of Woodland Road adjacent to the rail corridor and the MMAL site boundary (adjacent to EPA Designated Source Areas 4 and 3 respectively);
- 1,1-DCE was detected mid-way along Woodland Road at soil vapour bores SV_EPA30 (1,380 µg/m³) and SV_EPA35A (594 µg/m³), immediately west of the MMAL site boundary between EPA Designated Source Areas 3 and 4;
- Little or no VCH were reported in soil vapour along the line of Bradley Grove 100 m west of the MMAL site at soil vapour bores SV_EPA49, SV_EPA52, SV_EPA54A, SV_EPA56 and SV_EPA51; and
- Higher VCH concentrations were reported at soil vapour bore SV_EPA40A located 80 m west of Bradley Grove (141 µg/m³) and SV_EPA42 located another 100 m north-west of SV_EPA40 (37.6 µg/m³).

These findings are consistent with the findings of previous soil vapour monitoring events conducted by Fyfe in 2014 and 2015 (Fyfe, 2014 and 2015), and BlueSphere in 2015 and 2016 (BlueSphere 2016a and 2016c).

10.1.2.2 Concentration Stability Assessment

The criteria for demonstrating soil vapour concentration stability (for TCE and total VCH concentrations) outlined in **Section 4.5** were applied to determine which soil vapour bores can be considered stable and well characterised, and which bores should be re-sampled as part of the second round of sampling. A spreadsheet showing the stability calculations is attached as **Appendix O**.

The following points are noted with respect to the stability and degree of characterisation of the sampled bores:

- All bores for which three sets of data are available met the stability criteria and could therefore be considered to be reliability characterised;
- The 4 m deep bores at SV_EPA33B and SV_EPA34B both showed a monotonic increasing trend in TCE concentration over the monitoring period, but in both cases, this monotonic trend was not evident in the corresponding 2 m bores (SV_EPA33A and SV_EPA34A);
- Some variation was seen in the 1,1-DCE concentrations at SV_EPA35A and SV_EPA35B for which only two data points were available. In both cases the latest concentration was much lower than the previous data point from September 2015; and
- Only two data points are available for seven bores installed by Fyfe in September 2015 (those numbered SV_EPA76 and above), as well as bores SV_EPA51, SV_EPA52, SV_EPA54A and SV_EPA56.

All off-site soil vapour bores were nominated for resampling in March 2018 to assess the soil vapour concentrations under late summer/ autumn conditions, with the exception of soil vapour bores SV_EPA76A and SV_EPA76B, which are the only off-site soil vapour bores located on private property. The shallow bore (SV_EPA76A) reporting all VCH concentrations <LOR in November 2017 and it was not considered necessary to further inconvenience the owner by resampling these bores in March 2018.

10.2 Round 2 – March 2018

10.2.1 On-Site Soil Vapour

The Round 2 on-site soil vapour data is presented in **Table T7**. Historical data is presented in **Table T8**. Field sheets are presented as **Appendix K** and the laboratory certificates are presented as **Appendix M**.

10.2.1.1 Concentration Stability Assessment

Soil Vapour Bores Installed in November 2017

Summaries of the soil vapour VCH data for the new on-site soil vapour bores are provided on **Figure F21** to **Figure F23**. As only two rounds of sampling data are available for these bores it was not possible to apply the formal stability assessment criteria. However, comparison of the two sets of data from November 2017 and March 2018 for the newly installed on-site soil vapour bores showed broadly consistent VCH concentrations between the two events with the following exceptions:

- A PCE concentration of 5,200 µg/m³ was reported in the deep (8m) bore BSE_SV01C. At the previous sampling event the PCE concentration was reported as <340 µg/m³. It is noted that PCE was reported as <LOR in the 4 m and 2 m bores at this location (BSE_SV01A and BSE_SV01B) in both November 2017 and March 2018; and
- A PCE concentration of 10,000 µg/m³ was reported in the deep (8m) bore BSE_SV03C. At the previous sampling event the PCE concentration was reported as <340 µg/m³. PCE was reported as <LOR in the 4 m and 2 m bores at this location (BSE_SV03A and BSE_SV03B) in both November 2017 and March 2018.

In general, it is considered that the soil vapour conditions, particularly at shallower depths, at these five locations has been well characterised.

Existing Soil Vapour Bores

Summaries of the new and historical soil vapour VCH data for the existing on-site soil vapour bores are provided on **Figure F21** to **Figure F23**.

The additional data was incorporated into the stability calculation spreadsheet (**Appendix O**) to assess whether the VCH contaminant concentrations could be considered well characterised following the additional round of sampling.

The following key points are noted:

- Soil vapour bores SV01 and SV_EPA62A failed the stability criteria and continued to show an increasing trend;
- Soil vapour bore SV_EPA66 passes the stability criteria following the additional sampling round;
- The four SV13 bores (1 m, 2 m, 4 m and 8 m) all reported much higher soil vapour VCH concentrations in March 2018 than in previous monitoring rounds. This was particularly true of the 1 m bore which reported a TCE concentration of 280,000 $\mu\text{g}/\text{m}^3$ which was an order of magnitude higher than the previous results from November 2017 and July 2015. Smaller increases were seen for the deeper bores at this location; and
- The three SV_EPA64 series bores that could not be located in November 2017 were sampled in March 2018. All depths recorded TCE concentrations greater than those reported at the previous monitoring event in July 2015, although the increases were less than a factor of 2.

It is possible that there may be a seasonal aspect to the variations in soil vapour concentrations seen along the southern boundary of EPA Designated Source Area 3 in March 2018, as previous monitoring events were conducted in winter and spring. It should be noted that, irrespective of the variations seen, the VCH concentrations in this area are known to be very high and following the demolition of the houses along Chestnut Court no potential human receptors are present in the area.

10.2.2 Off-Site Soil Vapour

The Round 2 off-site soil vapour data is presented in **Table T9**. Historical data is presented on **Table T10**. Field sheets are presented as **Appendix K** and the laboratory certificates are presented as **Appendix M**.

Summaries of the new and historical soil vapour VCH data for the off-site soil vapour bores are provided on **Figure F24** to **Figure F27**. As for the first round of sampling, the soil vapour contaminant concentration data showed a high degree of stability. The data confirmed the general distribution of contaminants as discussed in **Section 10.1.2.1**.

10.2.2.1 Concentration Stability Assessment

The additional data was incorporated into the stability calculation spreadsheet (**Appendix O**) to assess whether the VCH contaminant concentrations could be considered well characterised following the additional round of sampling.

The following key points are noted:

- The seven wells (SV_EPA51, SV_EPA52, SV_EPA54A, SV_EPA56, SV_EPA78A, SV_EPA78B and SV_EPA80) that had previously been sampled only twice, all satisfied the stability criteria after the additional round of sampling and can be considered adequately characterised;
- The 4 m deep bores at SV_EPA33B and SV_EPA34B continued to show an increase in TCE concentration over the last four events, but this was not evident in the corresponding 2 m bores (SV_EPA33A and SV_EPA34A); which passed the stability criteria;
- Bores SV_EPA35A and SV_EPA35B failed the stability criteria as the reported VCH concentrations (predominantly 1,1-DCE) were lower than those previously reported and indicated a strong downward trend since September 2015; and
- A relatively high PCE concentration of 2,800 $\mu\text{g}/\text{m}^3$ was reported in soil vapour bore SV_EPA32 in March 2018. This was notably inconsistent with the two previous monitoring rounds conducted in November 2017 and September 2015 which reported PCE concentrations of <340 $\mu\text{g}/\text{m}^3$.

10.2.2.2 Seasonal Variation

It was noted that in general the reported VCH concentrations from the second round of soil vapour sampling were slightly higher than those reported in November 2017. Prior to March 2018, the

previous major soil vapour monitoring rounds have all been conducted in spring (October 2014, September 2015, September 2016 and November 2017) when groundwater levels and the moisture content of unsaturated zone soils were likely to have been high. The only previous soil vapour sampling conducted during the dryer months of the year was a limited round of sampling conducted at eight locations by Fyfe in March 2015 (Fyfe, 2015). The TCE concentration data for the impacted shallow (2 m) wells that were sampled in March 2015 is presented in **Table 12** below. The data shows a clear trend of higher TCE concentrations in soil vapour from the two March events in comparison with the spring sampling events.

Table 12 Seasonal Variation in TCE Concentrations in Off-Site Shallow Bores

Sampling Date	SV_EPA33A	SV_EPA34A	SV_EPA57A	SV_EPA78A	SV_EPA80
Oct-14	940	920	36	-	-
Mar-15	1,400	1200	290	360	180
Sep-15	1,120	870	-	-	-
Sep-16	1,080	934	-	-	-
Nov-17	1,200	698	137	160	53.7
Mar-18	1,400	1000	210	480	140

This seasonal variation is likely to be attributable to the lower soil moisture content in March at the end of summer which increases the available pore space for VCH vapours to migrate upwards through the soil profile. While the data suggests some seasonal variation, the spring and autumn soil vapour concentrations varied by not more than a factor of 3.

10.3 Summary of Soil Vapour Data

10.3.1 On-Site Data

The VCH concentration data obtained from the newly installed soil vapour bores and the selected existing soil vapour bores provides additional confidence that the general distribution of VCH in soil vapour within the Audit areas is well understood. The data indicates that relatively low concentrations of VCH are present in shallow soil vapour within EPA Designated Source Area 4 and across much of the northern and central parts of EPA Designated Source Area 3. However, the data supports that very high VCH concentrations are present in soil vapour along the southern boundary of EPA Designated Source Area 3. Considerable variation in the (very high) concentrations were seen between monitoring events at some locations in this area. However, in the absence of any potential receptors in this area the observed variations are considered to be of little consequence given that the concentrations are known to be very high.

10.3.2 Off-Site Data

The off-site soil vapour data collected in November 2017 and March 2018 showed a high degree of consistency with previous data at the selected soil vapour bores, with only modest seasonal variations and other minor variations between monitoring events observed. It is considered that the consistency of the data was such that a high degree of confidence can be placed in the reliability of the soil vapour VCH concentration data when assessing risk to off-site receptors via the vapour intrusion pathway.

VCH soil vapour concentration contour maps were not produced from the data collected in this investigation as there were insufficient data points to produce meaningful contours. However, it is considered that the high degree of stability observed indicates that the contour maps produced from the soil vapour data collected in 2015 (**Figure F13** and **Appendix C**) provide a reliable picture of the general distribution of VCH in soil vapour at the soil vapour bores located in the off-site areas to the west of the MMAL site.

11 Downhole Geophysical Logging Results

The locations of the groundwater monitoring bores at which geophysical logging was undertaken in both September 2015 and November 2017 are shown on **Figure F8**. The logging reports supplied by Borehole Wireline (the geophysical logging contractor) for both rounds of work are attached as **Appendix P**. The logging report for the work conducted as part of this investigation includes the geophysical logging traces for each of the 23 groundwater monitoring wells correlated against the well construction log and the lithological log generated during installation of each well. A summary of the findings with respect to the lithology at each investigation location for both the September 2015 and November 2017 logging programs is provided in **Table 13**.

It is clear from the geophysical logging data that the lithology of the upper Quaternary (water table) aquifer comprises predominantly low permeability clay and sandy clay Quaternary sediments interspersed with irregularly distributed, laterally discontinuous, higher permeability gravelly/ sandy layers. The thickness, permeability and frequency of these higher permeability bands shows considerable spatial variability across the investigation area, which is likely to result in substantial differences in hydraulic conductivity in different portions of the investigation area.

The data has been summarised in cross sections showing the variation in total gamma count (in API units) with depth at a selection of wells forming two cross-sections. The first (**Figure F28**) runs in a north-west to south-east orientation from near the down hydraulic gradient extent of the VCH groundwater plume to near the south-east corner of the MMAL site. The second (**Figure F29**) runs in a south-east to north-west orientation from the southern part of Mitchel Park to the MMAL boundary with South Rd near the former administration building. Increased clay content is indicated on the geophysical logs by a higher gamma count (shown as a red line on the left hand side of each log) and is illustrated by the inferred clay content trace shown on the right hand side of each log, where a thin yellow signal indicates low clay content and a thick orange signal indicates high clay content.

Figure F28 shows a clear increase in the clay content of the sub-surface below the water table from north-west to south-east. Inspection of the clay content data from depths below the water table at all wells shows that the wells can be broadly divided into four regions as follows:

- Wells located in Marion and the western part of Mitchell Park (e.g. DW_BSE15, BSE_DW12, BSE_DW11, BSE_DW06, BSE_DW03) show a low clay content below the water table, suggesting relatively high permeability in this area.
- Wells located within the eastern part of Mitchell Park, closer to the MMAL site, (e.g. MW_EPA20, MW_EPA13 and EPA_MW14) showed slightly higher clay content, suggesting lower permeability.
- Wells located within the south-western portion of the former MMAL site (e.g. MWS14_08, MWS13_01 and BSE_GW01) showed substantially higher clay content, indicative of relatively low permeability.
- Wells located in the vicinity of the former Reckitt & Colman site and the south-eastern corner of the MMAL site (e.g. BSE_GW10, MW_EPA2, MWS14_11, W6, GW42_URS and MWS14_07) show relatively very high clay content soils below the water table suggesting that the permeability in this area is likely to be relatively very low.

Analysis of the data shown on **Figure F29** shows the following trends:

- Moderately high clay content below the water table in the wells located in Mitchell Park to the south-west of the MMAL site (MW_EPA18, MW_EPA10A, MW_EPA11, MW_EPA12). This indicates that the permeability is likely to be relatively low in this area.
- Higher clay content in wells located in the south-western corner of the MMAL site (MWS14_08, BSE_GW08, BSE_GW07, and MWS13-01), suggesting low to very low permeability in this area.

- Lower clay content below the water table in wells located in the central and northern portions of Section 14 (BSE_GW01 and MWS11_01), indicating that the permeability may be slightly higher in this area relative to the south-western corner of the MMAL site.
- Higher clay content in well MWS11_03 located within the TAFE building; and
- Much lower clay, content suggesting higher permeability, at well MWS06_06 located on the eastern boundary of the MMAL site approximately 400 m north-east of Section 14.

Table 13 Summary of Geophysical Logging Findings

GW Well ID	Logging Depth (m)	Standing Water Level Nov/Dec 2017 (m btoc)	Conductivity Logging	Comments
November 2017 Logging Program				
BSE_DW02	11.95	6.99	No	Low gamma sand at ground level extending to 1.5m, underlain by high gamma clays to 6.5m. Remainder of the geology intersected is low gamma sands with a thin band of clays between 8.5m and 10m.
BSE_DW03	13.05	8.73	Yes	High gamma clays close to GL underlain by sands to 3.0m. An interval of clay between 3.0m and 4.5m. Low gamma sands between 8.3m and 9.5m
BSE_DW07	11.5	6.68	No	Two low gamma sand units identified. Upper layer between 1.5m and 2.1m. Large, lower layer between 6.5m and 8.5m. Sands units separated by high gamma clays.
BSE_DW08	12.91	7.61	Yes	Low gamma sands close to GL and extending to 3.0m. Slight reduction in gamma values below 7.75m indicates an increase in the sand content. Thin sand at 9.3m.
BSE_DW11	9.46	6.90	No	Low gamma sands close to GL extending to 2.5m and underlain by clays. Low gamma sands below 5.5m separated by a thin clay at 6.6m.
BSE_DW12	11.81	6.99	Yes	Mainly high gamma clays with thin low gamma sands – specifically at 4.3m, at 5.2m, between 6.2m and 7.1m. Low gamma sand below 8.3m.
BSE_DW15	8.65	5.98	Yes	High gamma clays close to GL. A large low gamma sand unit below 5.5m.
BSE_DW16	11.38	6.52	No	Primarily high gamma clays from GL to 7.75m, except for a thin sand at 2.3m. Increasing low gamma sands below 7.75m.
BSE_GW01	12.94	7.69	Yes	Large low gamma sand between 2.5m and 4.5m. Another sand unit identified between 8.7m and 11.2m.
GW45_URS	20.05	Dry	Yes	Low gamma sand unit between 2.3m and 3.6m. Below this the intersection is dominantly clay becoming slightly sandier below 12.5m
MW_EPA2	17.2	11.99	No	Low gamma sands from GL to 4m below which the geology becomes increasingly clay rich with depth. Below 11.2m, sand percentage increases. Thin sand units at 2.4m at 14.0m and at 15.2m.
MW_EPA10A	15.01	12.30	Yes	Low gamma sands from GL to 4.0m. Clay dominated below 4.0m. Sands unit identified between 2.4m and 14.5m.

Table 13 Summary of Geophysical Logging Findings

GW Well ID	Logging Depth (m)	Standing Water Level Nov/Dec 2017 (m btoc)	Conductivity Logging	Comments
MW_EPA11	20.1	12.92	No	Low gamma sands from GL to 3.8m which is underlain by thick high gamma clays. Sandier between 13.5m and 19.4m.
MW_EPA12	16.1	9.30	No	Moderate to high clay clays dominate the intersection. Thin sand units at 5.3m, at 7.5m, at 10.5m and at 15.2m.
MW_EPA14	13.9	9.70	No	Moderate to high gamma clays dominate the intersection. Sand unit identified between 6.0m and 7.5m.
MW_EPA15	11.87	9.40	No	Lower gamma sands tend to dominate the intersection and numerous thin sand units identified.
MW_EPA19	19.7	12.46	No	Lower gamma sands from GL to 9.3m with sand units at 6.0m and at 8.5m. High gamma clays dominant below 9.3m with some thin sands at 16.6m and at 17.4m.
MW_EPA26	10.35	7.91	Yes	Two sand units identified between GL and 1.8m and between 9.2m and 10.0m – separated by high gamma clays. Some very thin low gamma sands between 2.0m and 4.5m.
MW_EPA30	12.85	10.08	No	Overall lower gamma signature suggests a sandier intersection. Thin sand units identified at 1.3m, at 4.0m, at 8.8m and between 10.8m and 12.5m.
MW_EPA31	13.4	10.52	No	Overall lower gamma signature suggests a sandier intersection. Sand units identified between GL and 1.1m, at 6.9m and between 12.6m and 13.3m.
MW_EPA32	13.29	11.54	No	Lower gamma signature from GL to 8.6m. Higher gamma clay between 9.5m and 12.0m. Thin sands between 6.3m and 8.7m and below 12.0m.
MWS11_01	15.01	7.98	No	Sandy and/or sand units from GL to 5.0m underlain by dominantly clays. Other sand units identified between 8.0m and 9.2m and between 11.2m and 11.8m.
W6	17.2	Dry	No	Low gamma sand below GL to around 3.6m. High gamma clay dominant below 3.6m, although thin lower gamma sands commonly interbedded with the clays.
September 2015 Logging Program				
BSE_GW02	12.5	9.78	No	High gamma clays close to GL. Thin low gamma sands/gravels at 1.2m and 5.3m.
BSE_GW04	13.8	9.91	No	High gamma clays close to GL. Low gamma sand/gravel between 2.3m and 2.8m, and below 11.3m.

Table 13 Summary of Geophysical Logging Findings

GW Well ID	Logging Depth (m)	Standing Water Level Nov/Dec 2017 (m btoc)	Conductivity Logging	Comments
BSE_GW05	12.9	8.72	No	High gamma clays at 0.5m, at 3.0m, at 4.7m and at 8.1m. Low gamma sand/gravel between 1.1m and 2.0m and below 8.3m.
BSE_GW06	12.7	9.85	No	High gamma clays close to GL. Low gamma sand/gravel at 1.1m, and at 12.0m.
BSE_GW07	13.6	9.24	No	High gamma clays close to GL. Low gamma sand/gravel at 3.0m, at 5.5m and at 10.1m. Interbedding suggested. Becoming more clay rich below 8.5m.
BSE_GW08	12.9	9.27	No	High gamma clays close to GL. Low gamma sand/gravel at 4.7m.
BSE_GW10	16.0	11.80	No	High gamma clays close to GL. Lower gamma sands/gravels suggested between 4.1m and 8.8m, and at 13.2m.
GW42_URS	13.5	7.99	No	Lower gamma sands/gravels from GL to 4.1m. High gamma thin clays at 7.5m and 8.4m.
MW_EPA3	16.3	Dry*	No	Lower gamma sands/gravels from GL to 3.1m. Interbedded thin sands/gravels between 9.0m and 10.5m.
MW_EPA6	16.0	Dry*	No	Predominantly moderate gamma throughout suggesting clay rich formation. Thin sands/gravels suggested at 5.8m, at 9.7m and at 15.1m.
MW_EPA7	16.0	Dry*	No	Predominantly moderate gamma throughout, increasing below 9.9m where gamma response suggests an interbedded nature.
MW_EPA10A	15.0	12.30	Yes	Sand/gravel indicated by lower gamma between 12.3m and 14.4m.
MW_EPA13	14.0	10.79	No	Predominantly moderate gamma throughout suggesting clay rich formation. Thin sand/gravel suggested at 6.2m.
MW_EPA16	12.0	8.68	No	Sands/gravels indicated between 4.2m and 5.3m and between 10.6m and 11.3m.
MW_EPA18	13.5	11.91	No	Predominantly moderate gamma throughout suggesting clay rich formation. Thin lower gamma sands/gravels below 11.6m.
MW_EPA19	20.0	12.46	No	Predominantly moderate gamma throughout suggesting clay rich formation. Becoming less clay rich between 15.5m and 19.0m.
MW_EPA20	12.0	9.67	No	Interbedded low gamma sands/gravels between 1.3m and 5.7m. Sands/gravels suggested below 9.9m

Table 13 Summary of Geophysical Logging Findings

GW Well ID	Logging Depth (m)	Standing Water Level Nov/Dec 2017 (m btoc)	Conductivity Logging	Comments
MW_EPA21	12.0	8.43	No	Thin low gamma sands/gravels between 9.8m and 10.8m.
MW_EPA22	13.5	9.25	No	Predominantly moderate gamma throughout suggesting clay rich formation. Thin low gamma sand/gravel at 11.9m.
MW_EPA23	9.0	6.72	No	Clay rich interval between 2.8m and 4.3m. No sand/gravels suggested.
MW_EPA29	11.0	9.68	No	Predominantly moderate gamma throughout suggesting clayey formation. Lower gamma below 9.5m indicated more sands/gravels.
MWS06_02	13.4	9.39	No	Thin low gamma sands/gravels at 3.2m and 3.9m.
MWS06_06	17.5	15.32*	No	Predominantly moderate gamma throughout suggesting clayey formation.
MWS10_02	11.0	6.31	No	Thin interbedding between 1m and 4.7m. More sand/gravel between 7.8m and 10.3m.
MWS11_03	15.0	7.12	No	Predominantly moderate gamma throughout suggesting clay rich formation.
MWS13_01	15.0	7.50	Yes	Interbedding indicated.
MWS13_02	13.8	8.51*	No	Interbedding between 3.1m and 8.0m. Lower gamma sands/gravels indicated between 8.1m and 9.7m.
MWS14_01	18.0	10.34	No	Low gamma sand/gravel between 5.7m and 6.05m.
MWS14_04	19.5	15.4*	No	Low gamma sand/gravel between 3.0m and 5.0m.
MWS14_05	18.0	5.03	No	Predominantly moderate gamma throughout suggesting clay rich formation. Thin sand/gravel at 6.3m.
MWS14_07	18.0	9.02	No	High gamma clay zone between 4.1m and 5.3m. Lower gamma sand/gravel close to GL and below 11.1m.
MWS14_08	22.0	11.71	No	Predominantly moderate gamma throughout suggesting clay rich formation. Coarsening down signature to sand/gravel between 2.5m and 5.6m.
MWS14_11	15.0	Dry*	No	High gamma clays between 5.0m and 7.0m. Sand/gravel suggested by lower gamma at 2.1m and at 3.95m.
MWS18_02A	15.0	10.30	No	Predominantly moderate gamma throughout suggesting clay rich formation.

Table 13 Summary of Geophysical Logging Findings

GW Well ID	Logging Depth (m)	Standing Water Level Nov/Dec 2017 (m btoc)	Conductivity Logging	Comments
MWS18_04	15.0	10.15*	Yes	Interbedded nature suggested. Lower gamma signature between 1.1m and 1.8m, between 2.5m and 3.2m and from 9.0m to 9.6m.
MWS18_07	17.3	9.16	No	Predominantly moderate gamma throughout suggesting clay rich formation. Low gamma sand/gravel between 5.0m and 5.3m.
MWS19_25	17.0	10.81*	No	Predominantly moderate gamma throughout suggesting clay rich formation.
W5	20.0	13.33	Yes	Low gamma sand/gravel between 3.0m and 5.0m. High gamma clay between 5.1m and 5.8m.
W7	17.8	11.34	Yes	Predominantly moderate gamma throughout suggesting clay rich formation. Highest gamma above 2.9m.

Notes: * indicates that standing water levels measured in September 2015 have been used as the well was not gauged in Nov/Dec 2017.

12 Conclusions

The following conclusions are drawn from the investigations described above:

- The groundwater contours inferred from the groundwater gauging round conducted in November/December 2017 are generally consistent with those obtained from previous gauging rounds and support the previous findings that the groundwater flow direction across the MMAL site is broadly in a west to north-westerly direction. The groundwater flow direction swings more to the north-west down-gradient of the MMAL site in Mitchell Park and Marion.
- VCH groundwater concentration data obtained from resampling of selected on-site groundwater monitoring wells (located within the former MMAL site) in January and April 2018 showed a high degree of consistency with data from previous recent monitoring events. The data obtained from the two rounds of sampling broadly supports the inferred distribution of VCH contamination in on-site shallow groundwater inferred in the CSM report (BlueSphere, 2017). It is therefore considered that the nature and extent of the VCH plume beneath, and immediately up hydraulic gradient of, EPA Designated Source Areas 3 and 4 is well characterised. This directly addresses IAA Data Gap 3 and also assists in addressing IAA Data Gap 1.
- The extent of the off-site groundwater VCH plume within the uppermost Quaternary aquifer in Mitchell Park and Marion has been well delineated to the 5 µg/L level of detection. The concentrations of VCH in groundwater have shown a high degree of stability over the monitoring period from 2014 to 2018, suggesting that the plume is broadly stable. Inferred groundwater TCE concentration contours from the January 2018 data were very similar to those inferred from monitoring data collected in 2016. It is therefore considered that the data provides additional confidence that the nature and extent of the off-site VCH plume has been adequately characterised, and that the plume has been stable over the monitoring period. This directly addresses IAA Data Gap 6.
- Two rounds of sampling data from the three sets of three on-site soil vapour bores installed in EPA Designated Source Area 4 indicate that the concentrations of VCH in shallow soil vapour (2 m bgl) are low (<20 µg/m³) in EPA Designated Source Area 4. In conjunction with data obtained as part of the concurrent Source Investigation, the additional soil vapour data collected assists in addressing IAA Data Gap 2 in relation to EPA Designated Source Area 4.
- The additional on-site soil vapour data collected in November 2017 and March 2018 from a number of existing soil vapour bores and two newly installed sets of bores within EPA Designated Source Area 3 provided further evidence of very high soil vapour VCH concentrations along the southern boundary of EPA Designated Source Area 3 (adjoining the Relocation Area). Much lower soil vapour VCH concentrations were reported in the central and northern portions of EPA Designated Source Area 3. In conjunction with data obtained as part of the concurrent Source Investigation, the additional soil vapour data collected assists in addressing IAA Data Gap 2 in relation to EPA Designated Source Area 3 and also assists in addressing Data Gap 1.
- The additional off-site soil vapour data collected in November 2017 and March 2018 shows a high degree of consistency with previous data collected between 2014 and 2016. This suggests that the VCH concentrations in shallow soil vapour at a depth of 2 m within Mitchell Park are broadly stable and have been well characterised at the existing soil vapour bores. Some seasonal variation in off-site VCH soil vapour concentrations between spring and autumn sampling events were noted. This additional monitoring data assists in addressing IAA Data Gap 8 and can be used in conjunction with the results of the basement survey being conducted separately to refine the uncertainties with regard to current or future soil vapour intrusion risks identified in the HERA (BlueSphere, 2017a).
- Geophysical logging data from 22 groundwater monitoring wells logged as part of this investigation, and 36 wells logged previously in 2015, indicates that the lithology of the upper Quaternary (water table) aquifer comprises predominantly low permeability clay and sandy

clay, interspersed with irregularly distributed, laterally discontinuous, higher permeability gravelly / sandy layers. The thickness, permeability and frequency of these higher permeability bands shows considerable spatial variability across the investigation area, which is likely to result in substantial differences in hydraulic conductivity in different portions of the investigation area. Some clear spatial patterns in the saturated zone lithology were apparent. These trends can be summarised as follows:

- A zone of relatively high clay content in saturated zone soils was present in the vicinity of the Relocation Area, the former R&C site and the south-west corner of the MMAL site, suggesting that, in general, the saturated zone permeability is likely to be relatively low in this area;
- Slightly lower clay contents in saturated zone soils were seen to the north of Section 14 in the vicinity of the current TAFE building, suggesting that slightly higher permeabilities are likely to be seen in this area; and
- The clay content of the saturated zone soils is seen to decrease substantially with distance to the north-west along the axis of the groundwater plume, with a sandy lithology dominant in the saturated zone in the western portion of Mitchell Park and in Marion. This suggests that the permeability of the upper Quaternary aquifer is likely to be substantially greater within the suburbs to the west of MMAL site than in the immediate vicinity of Section 14.

This data directly addresses IAA Data Gap 3.

It is therefore concluded that the data obtained successfully addresses the specific objectives listed in **Section 1.8** and provides additional data necessary to address the IAA data gaps identified in **Section 1.6** (Cardno, 2017).

Furthermore, the investigations described above, in conjunction with other investigations described in **Section 1.6**, facilitate the achievement of the general objectives specified in the VSCAP by providing additional data to:

- Assist in determining the nature and extent of any VCH groundwater contamination within the MMAL site from EPA Designated Source Areas 3 and 4; and
- Assess the risks from any VCH groundwater contamination in the groundwater migrating off the western boundary of the MMAL site from EPA Designated Source Areas 3 and 4.

This data obtained from this investigation, in conjunction with data obtained from the concurrent Source Investigation and basement survey, will be used to inform the development of an updated CSM for the former MMAL site and surrounding areas, and to update and refine the HERA for off-site residents to the west of the MMAL site.

13 Limitations

This report was prepared for the sole use of Renewal SA, the Crown in right of the State of South Australia and any site contamination auditor appointed to undertake a site contamination audit and should not be relied upon by any other person. None of BlueSphere Environmental Pty Ltd or any of its related entities, employees or directors (each a **BlueSphere Person**) owes a duty of care (whether in contract, tort, statute or otherwise) to any third party with respect to or in connection with this report and no BlueSphere Person accepts any liability for any loss or damage suffered or costs incurred arising out of or in connection with the use this report by any third party.

The report has been prepared with the objectives and scope of work outlined in the proposals dated 19 December 2017 and 21 March 2018. The work was carried out in accordance with the Panel Deed executed 19 January 2018.

The conclusions and recommendations provided in this report are based on available information and it is possible that different conclusions and recommendations could be made should new information become available, or with changing site conditions over time. These opinions, conclusions and recommendations are subject to uncertainty given the potentially complex nature of any subsurface environment. Variation in soil and groundwater conditions may vary significantly between the specific sampling and testing locations and other locations at the site.

The report will not be updated if anything occurs after the date of this report and BlueSphere Environmental Pty Ltd will not be obliged to inform any person of any matter arising or coming to its attention after that date.

References

- AECOM, 2017. Updated Environmental Health Risk Assessment. Monroe Clovelly Park. AECOM Services Pty Ltd. 30 June 2017.
- ANZECC/ ARMCANZ 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. National Water Quality Management Strategy, 2000.
- BlueSphere 2016a. Tonsley VSCAP Investigations: Progress Factual Report No. 1. BlueSphere Environmental Pty Ltd, 10 May 2016.
- BlueSphere 2016b. Tonsley VSCAP Investigations. Mitchell Park Delineation Drilling – June 2016. BlueSphere Environmental Pty Ltd, 22 July 2016.
- BlueSphere 2016c. Tonsley VSCAP Investigations: Stage 2 Delineation Drilling Mitchell Park and Marion – August / September 2016. BlueSphere Environmental Pty Ltd, 17 November 2016.
- BlueSphere 2017a. Tonsley VSCAP Investigation: Human Health and Environmental Risk Assessment. Tonsley Development, Former MMAL Site, Clovelly Park, SA. 17 January 2017
- BlueSphere 2017b. Conceptual Site Model (CSM): Tonsley VSCAP Investigation – Revision 03.
- BlueSphere, 2017c Tonsley VSCAP Investigations Further Groundwater and Soil Vapour Investigations Sampling and Analysis Quality Plan (SAQP). Tonsley Development, Former MMAL Site, Tonsley, SA . 20 October 2017.
- Cardno 2017. Interim Audit Advice – Tonsley VSCAP. 1284 South Road Tonsley, South Australia 5042. Project Reference CLP215164. Cardno Victoria Pty Ltd. 27 February 2017.
- CRC CARE 2013, Petroleum hydrocarbon vapour intrusion assessment: Australian guidance. CRC CARE Technical report No. 23. CRC for Contamination Assessment and Remediation of the Environment, Adelaide, Australia.
- Davis, GB, Patterson, BM & Trefry, MG. 2009. Field Assessment of vapours, CRC CARE Technical report no. 13, CRC for Contamination Assessment and Remediation of the Environment, Adelaide, Australia.
- Fyfe 2014. Clovelly Park/Mitchell Park Environmental Assessment. Final Report, EPA REF 05/17900, 61324, 3 December 2014.
- Fyfe 2015. Mitchell Park, South Australia Validation Assessment Works. Final Report, EPA REF 05/17900, 61324, 2 July 2015.
- Greencap, 2017. Detailed Site Investigation – Tonsley SANZ. Suburban Activity Node Zone – Tonsley. Greencap. October 2017..
- Land and Water Biodiversity Committee 2012, Minimum Construction Requirements for Water Wells in Australia, 3rd edition.
- Mud 2017. Site Contamination Audit Report, Renewal SA, Residential Audit Area – Suburban Activity Node Zone, Portion of Former Mitsubishi Motors Australia Limited Site, Tonsley, Prepared by Adrian Webber (ME-007_ (EPA Reference 61286), 7 December 2017.
- National Environment Protection Council (NEPC), 2013. National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended 2013) (ASC NEPM).
- NHMRC 2008. Guidelines for Managing Risks in Recreational Waters. 2008.
- NHMRC 2011. (National Health and Medical Research Council) Australian Drinking Water Guidelines. <http://www.nhmrc.gov.au/guidelines/publications/eh52>. Updated November 2016 (version 3.3)

- NSW EPA, 2012. Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases, November 2012.
- PB 2008a. Stage 1 Environmental Site Assessment – Mitsubishi Motors Production Plant, Tonsley Park, South Australia. 08-0277-01-2145476A, 20 May 2008.
- PB 2008b. Stage 2 Environmental Site Assessment – Mitsubishi Motors Production Plant, Tonsley Park, South Australia. 08-0484-03-2145476A, 8 August 2008.
- PB 2009 Section 14 Assessment Report – MMAL Tonsley Park. 08-0172-01-2145476B, 13 March 2009.
- SA EPA 2003. South Australian Environment Protection (Water Quality) Policy 2003. (superseded by 2015)
- SA EPA 2007. Regulatory monitoring and testing - Groundwater sampling. June 2007
- SA EPA 2008 Site Contamination: How to determine actual or potential harm to water that is not trivial, 2008.
- SA EPA, 2009. Guidelines for the Assessment and Remediation of Groundwater Contamination, February 2009.
- SA EPA 2015. South Australian Environment Protection (Water Quality) Policy 2015
- USEPA 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4), EPA/240/B-06/001, February 2006.
- USEPA 2008. Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8), EPA/240/R-02/004, published November 2002, re-issued 7 January 2008.
- US EPA 2015. Regional Screening Levels. <http://www2.epa.gov/risk/regional-screening-table>
- WHO, 2011. Guidelines for Drinking-Water Quality, Fourth Edition. 2011. ISBN 978 92 4 154815 1. World Health Organisation.