ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

REPORT NO. **210074_V4**

REMEDIATION ACTION PLAN FOR THE FORMER SOUTH MELBOURNE GASWORKS, ALBERT PARK, VICTORIA

ENVIRONMENTAL EARTH SCIENCES VIC
REPORT TO CITY OF PORT PHILLIP
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VERSION 4

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EXECUTIVE SUMMARY

Environmental Earth Sciences was commissioned by City of Port Phillip (CoPP) to prepare a remediation action plan (RAP) for the former South Melbourne Gasworks site, located at 21 Graham Street, Albert Park, VIC (the site).

The objective of the RAP is to explore available technologies and provide a strategy that best utilises the available resources. The RAP also documents the validation program for the remedial works (where required).

Endorsement of the remediation strategy and RAP, including supporting documentation and management plans will be sought from the appointed auditor, Peter Nadebaum of GHD Pty Ltd, as part of a 53V audit.

Soil
Isolation and Capping has been demonstrated as the most suitable way to manage the soil issues at the site due to the heterogeneity of the historical site capping and reported impacted soil and various gasworks waste across the site.

The proposed isolation and capping soil remediation option with appropriate control methods would also minimise or prevent odour, noise and dust issues that may negatively impact neighbouring residents and businesses if another remediation option was selected.

Groundwater
Environmental Earth Sciences considers the risk posed by the current groundwater status is low and the implementation of active or *in-situ* remediation of groundwater at the site is considered to be impracticable based on the following reasons:

- given the fact that the majority of the groundwater discharging from the site is captured via the surrounding sewer network (acting as a physical barrier) except to the east of the site;
- low likelihood of use of the groundwater for any beneficial uses due to the availability of reticulated mains water;
- low yield of the Brighton group aquifer; and
- the cost of implementing the most feasible and cost effective remedial approach will not commensurate with the benefits that will be achieved.

Based on our assessment of the potential groundwater remediation options and for reasons stated above, the most effective and practical way of managing the groundwater impacts is not to undertake any active or passive groundwater remediation other than the implementation of a regular groundwater monitoring (monitored natural attenuation) program as detailed below. However, in the residential area to the north east of the site, despite the low likelihood of use of the groundwater for the relevant extractive beneficial uses such as potable water, stock watering, agricultural parks and garden, industrial water use, primary contact recreation and similarly for building and structures, these potential beneficial uses cannot be discounted in this area and therefore implementing a Groundwater Quality Management Plan (GQMP) is recommended.

In addition, the Interim Contamination Management Plan (ICMP) will be updated to incorporate the required management during the proposed remediation works and to address the long term management of the site.

On behalf of
Environmental Earth Sciences VIC

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1 INTRODUCTION

Environmental Earth Sciences was commissioned by the City of Port Phillip (CoPP) to prepare a remediation action plan (RAP) for the former South Melbourne Gasworks site, located at 21 Graham Street, Albert Park, Victoria. The site location map is presented in Figure 1.

The site was formerly the manufacturing area of the South Melbourne Gasworks (SMG), and operated from 1871 to 1965, with some aspects remaining functional until 1971. The site was redeveloped and has been used as a park since the 1980's by the CoPP.

The site is currently managed in accordance with two Interim Contamination Management Plans (ICMPs); one applicable to the Southport Community Nursing Home and the other to the Gasworks Arts Park. The ICMPs are subject to changes and amendments pending further investigation, remediation and/or management.

The purpose of this RAP is to provide a strategy to mitigate the potential for un-acceptable human health and environmental risks in relation to the presence of residual soil and groundwater impacts and explore available technologies that best utilises the available resources in a safe manner. The RAP also documents the validation program for the remedial works (where required).

The preferred approach will adopt a risk based cleanup or strategy, to the extent practical to achieve an acceptable outcome that are technically, logistically and financially feasible. In addition, the selected strategy will need to take into account CoPP future landscaping plan and to provide a management plan for any remaining contamination suitable for safe long term use of the site as a park.

Environmental Earth Sciences completed the assessment of the suitability of the existing cap across the site in January 2011 and the results indicated the following:

- variability of the historical soil capping layer;
- presence of elevated concentrations of polycyclic aromatic hydrocarbons (PAH); and
- presence of gasworks waste within the top 0.5m of soil across the majority of the site in various lithologies.

Given the distribution of contamination is widespread and thus visually identifying and delineating the areas of contamination can be considered difficult, it is recommended that various remediation options should be considered and therefore this RAP has been produced for CoPP to address these issues, taking into account CoPP future landscaping plans.

1.1 Contents of RAP

This RAP describes the proposed remediation strategy and environmental management that relates to the environmental and health risks associated with TPH/PAH impacted soil, the presence of gasworks waste including ash, coke, clinker, solid and viscous tar and spent oxides and groundwater impacts. The RAP contains a compilation of all available data and Environmental Earth Sciences interpretation of that data.

The RAP provides guidance for implementation of the proposed remediation strategy of the park in-conjunction with the proposed re-landscaping plan.

1.2 Remediation Objectives

The primary remediation objective is to describe the management and remediation actions to be implemented to ensure that the site is suitable for the current use as park and to prevent the potential unacceptable risks to human health and environment in relation to the presence of residual soil and groundwater impacts.

1.3 Regulatory Compliance

The following details the regulatory framework to be considered:

1.3.1 Soil

State Environment Protection Policy - Prevention and Management of Contamination of Land (Land SEPP) applies to the management of soil contamination issues in Victoria. The goal of this policy is

"To maintain and where appropriate and practicable improve the condition of the land environment sufficient to protect current and future beneficial uses of land throughout Victoria"

1.3.2 Beneficial Uses of Soil

The beneficial uses to be protected for commercial land use in accordance with the State Environment Protection Policy, *Prevention and Management of Contamination of Land* (Land SEPP 2002) are as follows:

- modified ecosystems;
- human health;
- buildings and structures;
- aesthetics; and
- production of food and flora and fibre.

1.3.3 Adopted soil quality investigation levels

Environmental Earth Sciences refers to the NEPC (2013), *National Environment Protection (Assessment of Site Contamination) Amended Measure 2013* (here onwards referred to as the NEPM 2013) for environmental and health based investigation threshold levels for contaminant concentrations in soil. Further discussion has been included in Section 6.1.

1.3.4 Groundwater

State Environment Protection Policy (Groundwaters of Victoria), 1997 (Groundwater SEPP) applies to management of groundwater contamination issues in Victoria. The goal of the policy is:

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

The Groundwater SEPP defines beneficial uses of groundwater on the basis of background salinity, measured as TDS. Groundwater is polluted where current and/or future potential beneficial uses for the relevant segment are precluded. Beneficial uses of groundwater are considered precluded when relevant groundwater quality objectives have been exceeded, or where non-aqueous phase liquid (NAPL) is present.

1.3.5 Relevant groundwater segment

Based on the TDS values considered to be background in the area of SMG the groundwater is classified as Segment A_2. The protected beneficial uses for Segment A_2 are provided in Section 1.3.6.

1.3.6 Beneficial uses of groundwater

In accordance with the Groundwater SEPP, the protected beneficial uses for Segment A_2 groundwater are as follows:

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

1.3.7 Adopted groundwater quality investigation levels

In accordance with the Groundwater SEPP, groundwater quality investigation levels for beneficial uses are primarily sourced from the Australian Water Quality Guidelines for Fresh and Marine Waters, published by the Australian and New Zealand Environment and Conservation Council (ANZECC). Where no impacts are listed, for example, stock watering and primary contact recreation, the drinking water values should be adopted.

Given that groundwater at the site, as defined under the Groundwater SEPP, has been assessed as Segment A2, and considering the beneficial uses listed in the above section, levels in order to assess impact to potential groundwater beneficial uses (refer to Table 1).

TABLE 1 GROUNDWATER GUIDELINE SOURCE

Beneficial Use	Adopted Guideline Source
Maintenance of Ecosystems	ANZECC/ ARMCANZ (2000) and Hickey (2002) for nitrate criteria.
Acceptable Potable Water Supply	National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines, 2011.
Agricultural Park and garden	ANZECC/ ARMCANZ (2000) for irrigation
Potable Mineral Water Supply	This beneficial use is excluded as the groundwater does not display effervescent qualities as required under the definition of "potable mineral water" in the SEPP GoV and the area is not within a designated mineral water production zone.
Stock watering	ANZECC/ ARMCANZ (2000) for livestock
Industrial Water Use	No guidelines.
Primary Contact Recreation	NHMRC Guidelines for managing risks in recreational waters, 2008. Consumption of water during recreational events (i.e. in creeks or swimming pools using groundwater) has been considered, with criteria for non-volatile contaminants being set at 20 times the health criteria based on the assumption that recreational swimmers consume 100 mL of water per session, while NHMRC (2008) drinking criteria assume 2 L/day potable water consumption (also reported in ANZECC 1992, p3-7)
Buildings and Structures	No guidelines, although the effects of pH, sulfate and redox need to be considered.

1.4 Endorsement of Remediation Strategy

Endorsement of the remediation strategy and RAP, including supporting documentation and management plans will be sought from the appointed auditor, Peter Nadebaum of GHD Pty Ltd, as part of a 53V audit.

2 SITE CHARACTERISTICS

2.1 Location and site description

The site is currently owned by CoPP in conjunction with the State of Victoria. The CoPP currently operate as the 'Committee of Management' for the site. The site is situated in Albert Park and is bounded by Graham Street to the south; Pickles Street to the west; Richardson Street to the north; and Foote Street/Bridport Street to the east. Relevant property details are outlined in Table 1 and site location is illustrated on Figure 1.

The site covers an area of 3.21 hectares (ha) which includes 'Gasworks Arts Park' and 'Southport Community Nursing Home'. Gasworks Arts Park incorporates 2.67 ha of the site, consisting of grassed and landscaped areas, playground, BBQ and rotunda facilities, and small wetlands, all of which are linked by gravel access tracks. Residual gasworks buildings have been retained near the entrance of the park and used as a café, bookshop, art galleries, administration area and theatre, foyer and dressing room area While, the Southport site covers an area of 0.54 ha and is situated in the northeast corner of the SMG site (refer to Figure 2). The Southport Community Nursing Home occupies the majority of the Southport Site (fronting Richardson Street) and incorporates a brick building (i.e. nursing home), and open grass, paving and landscaped gardens.

The site is adjacent to the South Melbourne Gas Regulator which covers an area of 0.22 ha (i.e. Alinta Site) and is situated on the corner of Pickles and Richardson Streets. This area is covered by bitumen hard stand, and is occupied by a brick building in the northern portion of the site, which was a historical part of the original SMG infrastructure. The building housed the regulator station, which controlled pressure in the gas distribution pipes. It should be noted that this is not included within the investigation area.

TABLE 2 SITE DETAILS

Item	Details
Site Owners	City of Port Phillip / State of Victoria
Address	21 Graham Street, Albert Park, VIC
Site Area	3.21 Hectares
Local Government Authority	City of Port Phillip
Locality and site Map	Refer to Figure 1

2.2 Site history

2.2.1 General

In 1871 the South Melbourne Gas Company was established and leased 2.43 ha of land (including the South Melbourne Gas Regulator that covers an area of 0.22 ha, which is currently operated by Gas and Fuel Corporation of Victoria or also known as the Alinta site) on Pickles Street on the boundary of what are now, the suburbs of Albert Park and Port Melbourne. The construction of the Port Melbourne gas manufacturing plant was completed in 1873. Following completion, the South Melbourne Gas Company merged with Melbourne and Collingwood Gas Companies, forming the Metropolitan Gas Company.

A crown grant for the leased site was issued to the Metropolitan Gas Company in 1878, with an additional 1ha of land being purchased in the northern section (East of Pickles Street). The main manufacturing plant for Gasworks was developed in this area. The operation was expanded over the following years with establishment of the meter shop site (1885), No. 1 Holder site (1888) and laboratory and oil store (1913). Following a short period of closure during the depression, some sections of the plant never reopened. Gas manufacture, however continued up until 1971 with the Gas and Fuel Corporation of Victoria becoming the registered proprietor of all properties on-site in 1955.

The City of South Melbourne and Government of Victoria acquired the manufacturing plant in 1979, redeveloping it into Gasworks Park. In addition, the Southport Community Nursing Home was constructed on city owned land to the north-east of the site in 1981.

Gas and Fuel Corporation of Victoria still operate a small depot in the northern corner of the former gasworks site covering an area of 0.22 ha (i.e. Alinta site), however this is not part of the area under investigation and therefore the site covers an area of 3.21 hectares (ha) which includes 'Gasworks Arts Park' and 'Southport Community Nursing Home'.

Investigations into the contamination status of the site commenced around 1985 with EPA Victoria issuing a Clean Up notice to Gas and Fuel Corporation of Victoria in 1988. The Gas and Fuel Corporation commenced assessment and remediation across the site as required under the Clean up Notice, resulting in EPA Victoria declaring the site suitable for park use in 1992.

2.2.2 Historic gasworks site layout, operations and process

Gas manufacturing processes that are believed to have been undertaken on-site include:

- Coal carbonisation plant (CCP);
- Complete gasification plant (CWGP); and
- Oil Gas Plant (OGP).

Coal Carbonisation was noted (Golder Associates, 2004a) to have been undertaken in the west and central portions of the site in areas of the coke plant, retort houses and the coal store. Further purification of coal gas involved removal of sulfide, cyanide and ammonia.

The complete gasification plant was located in the south-western corner of the site and combined the vertical retorts process with that of water gas plants to maximise gas yield. Complete gasification generated a number of waste products including tar, oil and water emulsion and sulfate.

The oil gas plant was located in the north-western portion of the site. The OGP process was similar to that of the CWGP and produced similar wastes, however instead of coal tar, lampblack was produced.

Condensers within the eastern portion of the site were used to remove tars and water from coal gas. The tar was likely stored in adjacent tar tanks, or pumped to storage tanks located in the northern portion of the site. Note that it is likely or at least possible that tar and ammoniacal liquor was disposed to tar wells or off-site to nearby waterways.

Washers within the eastern portion of the site were used in removing naphthalene and ammonia from gas, and phenol and tar acid from ammonia waste. This process may have involved the use of water, oils, benzene, sulfuric acid and sodium hydroxide.

Purifiers were located in the north-eastern (above-ground) and south-eastern (below-ground) portions of the site. Gas purifiers were used for removal of sulfur and cyanide from the gas. Purifier wastes are expected to have concentrated levels of complexed cyanides, sulfur or sulfates, volatile PAHs and TPHs.

Historic infrastructure known to exist on site which includes the following in addition to the process infrastructure previously mentioned:

- boiler room;
- meter room;
- electrical sub-station;
- workshop and amenities (i.e. toilets, mess room and office);
- ferro-cyanide plant;
- sulfate store;
- liquor wells;
- tar tanks; and
- laboratory.

2.2.3 Current Site Uses and Condition

The site covers an area of 3.21 hectares (ha) and includes 'Gasworks Arts Park' and 'Southport Community Nursing Home'. Gasworks Arts Park incorporates 2.67 ha of the site, consisting of grassed and landscaped areas, playground, BBQ and rotunda facilities, small wetlands all linked by gravel access tracks. A number of community based events are held within the grounds of Gasworks Arts Park including monthly farmer's market, dog training, school holiday programs activities, and private and public functions.

Eleven buildings exist within the Gasworks Arts Park incorporating historic gasworks buildings retained as part of the site redevelopment and a few buildings, including administration buildings have been constructed since the redevelopment. Current buildings within Gasworks Arts Park are detailed below and locations are provided in Figure 2:

- Gasworks Arts Park Building 1 – *Sculpture Studio;*
- Gasworks Arts Park Building 2 – *Arts and Craft Studio;*
- Gasworks Arts Park Building 3 – *Ceramics Studio;*
- Gasworks Arts Park Building 4 – *Visual Arts Studio 1, 2 and 2;*
- Gasworks Arts Park Building 5 – *Gatehouse Building – Bookshop;*
- Gasworks Arts Park Building 6 – *Café and Angela Robarts-Bird Gallery;*
- Gasworks Arts Park Building 7 – *Main Theatre, Foyer and Dressing Room;*
- Gasworks Arts Park Building 8 – *Electricity Sub-station;*
- Gasworks Arts Park Building 9 – *Gasworks Admin Offices;*
- Gasworks Arts Park Building 10 – *Darkroom;* and
- Gasworks Arts Park Building 11 – *Studio Theatre – Workshop.*

The Southport site covers an area of 0.54 ha and is situated in the northeast corner of the SMG site (refer to Figure 2). The Southport Community Nursing Home (Building 12) occupies the majority of the Southport Site (fronting Richardson Street) and incorporates a brick building (i.e. nursing home), and open grass, paving and landscaped gardens.

The South Melbourne Gas Regulator Site (i.e. Alinta Site, Building 13) is situated on the corner Pickles and Richardson Streets and is not included within the investigational area.

This area is covered by bitumen hard stand, and is occupied by a brick building in the northern portion of the site, which was a historical part of the original SMG infrastructure. The building housed the regulator station, which controlled pressure in the gas distribution pipes. It should be noted that this is not included within the investigation area.

2.3 Previous remediation

It is understood that little remediation of on-site soil has been conducted, aside from excavation of 0.5 m of contaminated fill material and replacement with "clean soil" in the south-eastern corner of the site. Other remedial works have been limited to landscaping and the placement of topsoil and clay (capping layer) over the site (of unknown depth). However, no record has been made available documenting these works and the origin of the imported soil is not known.

Due to the lack of documentation in the past, the soil capping layer construction details have not been able to be confirmed. Although, it was written in the report that a minimum of 0.5 m of clean fill has been used in the south-eastern corner of the site; the outcome of the soil capping investigation undertaken by Environmental Earth Sciences (2011b) has identified the following:

- the cap was present/absent in some areas; and
- in some instances the supposed clean capping layer was also contaminated with gasworks waste and associated chemicals of concern.

2.4 Existing Site Contamination

A number of soil and groundwater investigation programs have been carried out at the site since 1988. Various consultants have carried out geotechnical and environmental assessments and groundwater monitoring and modelling, both within the site, and in the case of groundwater, at off-site locations.

The summary of historical and current soil and groundwater contamination is presented on Figures 4a to 13.

The key reports include:

- Golder Associates, 2004a. Report number 04613504/003 – '*Site History Review, Gasworks Park, Albert Park, Victoria.* Prepared for City of Port Phillip;
- Golder Associates, 2004b. Letter report number 04613504\504W006L - *Further Recommendations for Action, Gasworks Park, Albert Park.* Prepared for City of Port Phillip;
- Golder Associates, 2004c. Report number 04613504/010 - *Vapour and Edible Vegetation Risk Assessment, Gasworks Park, Albert Park.* Prepared for City of Port Phillip;
- Golder Associates, 2006a. Report number 05613732/018 - *Hydrogeological Conceptual Model, Gasworks Park Precinct, Albert Park.* Prepared for City of Port Phillip;
- Golder Associates, 2006b. Report number 05613732/018 - *Assessment of Groundwater Risks, Gasworks Park Precinct, Albert Park.* Prepared for City of Port Phillip;

- Golder Associates, 2006c. Report number 05613732/021 - *Installation and Sampling of Additional Groundwater Monitoring Wells, Gasworks Park Precinct, Albert Park.* Prepared for City of Port Phillip;
- Golder Associates, 2006d. Report number 05613732/022 - *Review of Contamination Status, Southport Community Residential Home, Albert Park.* Prepared for City of Port Phillip;
- Golder Associates, 2006e. Report number 05613732/039 - *Further Groundwater Investigation, North East of the Former South Melbourne Gasworks, Gasworks Park Precinct, Albert Park.* Prepared for City of Port Phillip;
- Golder Associates, 2007. Report number 05613732/059 - *Further Groundwater Investigation, Pickles Street Sewer, West of the Former South Melbourne Gasworks, Gasworks Park Precinct, Albert Park.* Prepared for City of Port Phillip;
- *Environmental Earth Sciences, 2011a Report number 210074 - April 2001 Groundwater investigations at former South Melbourne Gasworks;*
- *Environmental Earth Sciences, 2011b Report number 210074 – Site Capping Investigation v1 at former South Melbourne Gasworks;*
- *Environmental Earth Sciences, 2012 Report number 210074 – Indoor Ambient Air Vapour Investigation v2 at former South Melbourne Gasworks;* and
- GHD 2008, *Section 53V Environmental Audit – Interim Audit Report*, *Gasworks Site, Albert Park.*

A brief summary of the key reports together with their findings is presented in Appendix A.

2.5 Site topography and drainage

Surface topography at the site is relatively flat, sloping slightly from east to west. Regionally, land sloped towards Port Phillip Bay. Recorded site surface elevations range 2.105 to 2.670 metres Australian Height Datum (mAHD). Site surface topography is defined by fill material as does not represent natural conditions. However, it should be noted that mounding is present across the site.

2.6 Surface water

No surface water was observed during any of the environmental investigations. Surface water, if any, is expected to be limited to surficial stormwater runoff and ponding following rainfall.

2.7 Relevant local sensitive environment

The nearest surface water body to the site is Port Phillip Bay approximately 350 m south of the site (Figure 1).

2.8 Geology and soils

2.8.1 Site geology

The geological units encountered during site investigation works included:

- Port Melbourne Sand – the upper geological formation at the site, which discontinuously underlies the fill material, and has been identified in lenses up to 2.6 m thick in the southern portion of Gasworks Park;
- Brighton Group – encountered underlying fill material and, where present, the PMS. Brighton Group sediments have been identified extending to a maximum depth of 22 m BGL; and
- Older Volcanic Basalt – identified underlying Brighton Group sediments at approximately 18 m BGL in the north-eastern portion of the site.

2.8.2 Regional geology

According to the Geological Survey of Victoria (GSV 1974) *Melbourne 1:63,360 map sheet*, the surface geology at the site is the Recent Holocene aged (0-10,000 year old [yo]) Port Melbourne Sand, consisting of raised beach ridges of well sorted sand, shelly sand, minor silty or clayey sand.

Regionally, the Port Melbourne Sand formation in the region is sequentially underlain by the following formations:

- pliocene age (late Tertiary era – 5.3 to 1.8 myo) Brighton Group sediments, consisting of red-brown, yellow and white cross-bedded sands and silty sands (with clay);
- late lower tertiary eocene aged (36-53 Myo), olivine and titanaugite dense blue-black Older Volcanics basalt (OVB);
- eocene age (early Tertiary era – 54.8 to 33.7 myo) sand and silty-sands with clay, with pyritic and lignitic sands, of the Werribee Formation; and
- late upper silurian aged (400 Myo) Dargile Formation sandstone and siltstone.

2.9 Hydrogeology

2.9.1 Regional hydrogeology

According to DNRE (1995b) the uppermost aquifer beneath the site is associated with Port Melbourne Sand. The unit has an expected salinity range of 501-1000 mg/L total dissolved salts (TDS), classing the aquifer in this area as Segment A_2 of the State Environment Protection Policy (SEPP) *Groundwaters of Victoria* (GoV). Beneficial uses requiring protection under this segment include: maintenance of ecosystems; acceptable potable supply; agriculture, parks and gardens; stock watering; industrial use; primary contact recreation; and buildings and structures.

In review of previous investigations the pertaining hydrogeological conditions within the Gasworks Park precinct comprises of “one aquifer within the Brighton Group sediments, which is influenced predominantly by sea level in Port Phillip Bay and the sewer system surrounding the site” (Golder Associates, 2006a).

2.9.2 Site hydrogeology

Interpretation of previous groundwater investigations and monitoring events indentified several potential aquifers and aquitards beneath the site. The Brighton Group is the shallowest aquifer on site. It is underlain by the Older Volcanic Basalt, which is considered to be an aquitard due to its high clay content. As such it hydraulically insulates but does not isolate the deeper geological units from the Brighton Group sediments.

Based on TDS values south east of the site and in this general region, the groundwater has been classified as 'Segment A_2', with a TDS range of 501-1,000 mg/L. However, the quality of some of the non-impacted groundwater in the vicinity of the site does not support some of the protected beneficial uses.

A registered well search of the Department of Sustainability and Environment (DSE) '*Groundwater Database'* (Sinclair Knights Merz, 2010) has indicated that 291 wells are located within a 3 km radius of the site (refer to Table 2 below). Drilling geological logs of registered wells located within the vicinity of the site appear to be within the same or similar geological units as at the site. There have been no registered groundwater wells accessing the Dargile Formation within 3 km radius of the site. Most registered wells in the vicinity of the site are screened within the Quaternary and Tertiary sediments of the PMS and Brighton Group.

In this urban environment with a municipal reticulated water supply, the potential beneficial uses of potable water and mineral water supply are not considered to be realistic beneficial uses. However, the Victorian Groundwater Database (refer to Table 3) shows that some wells have been installed in the area for stock/domestic and irrigation purposes.

TABLE 3 SUMMARY OF REGISTERED BORES

Distance from site	Distance from site (m)	Number of wells	Use	Depth range (m)	Lithology	SWL (metres below ground level (m BGL))	Yield (L/sec)	EC
0 km – 1 km	115 – 970	21	unknown	4 – 150	Sand[b]	1.9[a]	0.8[a]	-
	66 – 832	16	investigation	4 – 10	Sand, silt, clay	-	-	-
	443 – 970	9	stock and/or domestic	3.91 – 32	Sand, basalt (> 17m)[a]	2 - 8	0.2 – 5.8	-
	844 – 889	3	irrigation	6 – 6.1	-	-	-	-
1 km – 2 km	1,182 – 1,911	13	stock and/or domestic	3 – 15	Sand and marl[a]	1.6 - 3	0.4 – 1.1	330[a]
	1,387 – 1,432	24	investigation	6	-	-	-	-
	1,001 – 1,909	20	unknown/other	14 – 52	Sand, basalt[b]	1.7[a]	0.7[a]	-
	1,078 – 1,972	52	investigation	2.5 – 20	Sand, silt	0.6 – 2.8	-	-

Distance from site	Distance from site (m)	Number of wells	Use	Depth range (m)	Lithology	SWL (metres below ground level (m BGL))	Yield (L/sec)	EC
2 km – 3 km	2,065 – 2,982	8	stock and/or domestic	4 – 10	-	-	-	-
	2,052 – 2,938	64	investigation	4 – 36	Clay, silt	2 – 3.4	-	-
	2,031 – 2,983	59	unknown/other	5 – 85	Sand, silt, clay, sandstone[a]	2 – 4.8	0.6[a]	-

Notes:
1. - = no data available.
2. [a] = information only available for one well in this field.
3. [b] = information only available for two wells in this field.

Based on historical reports, the contaminants being transported in groundwater from the site are captured by the sewer system and therefore there is currently negligible risk of impacted groundwater from Gasworks Park discharging to receiving waters (i.e. ecosystems) in the vicinity of the site (refer to Environmental Earth Sciences 2011a April 2011 Groundwater Report for further details).

Based on the historical reports, the groundwater is known to be contaminated. However, as the site is owned by the City and the State of Victoria, the extraction of groundwater on-site for any purpose can be controlled. Therefore, the potential beneficial uses are considered to be precluded but not relevant to the site.

In the area of gasworks-related groundwater contamination beneath private residences to the northeast of Richardson Street and northwest of Bridport Street, the extraction of groundwater is not currently prevented. Although the Brighton Group in this area has a particularly low potential yield due to a limited saturated thickness, the potential beneficial uses of primary contact recreation, irrigation and stock/domestic cannot be discounted in this area.

Regional groundwater flow in the basement Dargile Formation is towards Port Phillip Bay, therefore under natural hydraulic gradients, the groundwater flow direction would be expected to be towards the south to south west beneath the site. Previous groundwater assessments at the site (Golder Associates, 2006; 2006b and 2006c and Environmental Earth Sciences, 2011a and 2013) indicate that local groundwater flow in the shallow Brighton Group sediments is controlled by the sewer system(s).

Groundwater within the Brighton Group sediments beneath Gasworks Park generally flows radially from the site towards the nearby sewers aligned along Foote Street, Graham Street and Pickles Street, which act as groundwater sinks. This is consistent with the deepest drawdown being observed at the corners of the site, which is supported by previous investigations by Golders Associates. Groundwater levels in the Brighton Group beneath Gasworks Park are all below sea level due to the drawdown caused by the sewers. Therefore, the vertical gradient between the Older Volcanic Basalt and the Brighton Group is upwards, potentially contributing inflow to the groundwater system beneath the site.

An upward hydraulic gradient would prevent the downward migration of any contaminants of potential concern (CoPC) from the water table aquifer in the Brighton Group. Golder Associates noted that *"given the laterally extensive nature of the observed length of groundwater depression, it appears that leakage into the South Yarra main sewer and Hobsons Bay main occurs regularly along the sewer length rather than in discrete zones. As a result, groundwater is unable to migrate across the depression but rather discharges to the sewer*" (Golder Associates, 2006e). Thus, the distribution of CoPCs is interpreted to be controlled and contained both vertically and horizontally by the sewer network around the site.

This local groundwater flow system is dependent on the leakage of groundwater into the sewers. If leakage to the sewers were reduced significantly, the flow regime would change.

Following sample collection, slug tests (falling and rising head) were undertaken in selected wells utilising transducers. The slug tests were undertaken to confirm the hydraulic conductivity data (of the shallow water bearing zones) derived from previous assessments and evaluate the hydraulic conductivity of the deeper water bearing zones within the Brighton Group sediments and the median conductivity of the Brighton Group at the site was evaluated to be approximately 0.3 m/day.

3 CONCEPTUAL SITE MODEL

The purpose of a Conceptual Site Model (CSM) is to identify potential risks present at the site relative to the surrounding environment. The potential sources, potential transport mechanisms and exposure pathways, and potential sensitive receptors in close proximity to the subject property, based on the findings of this investigation and previous investigations, are presented in the sections below.

3.1 Potential sources of contamination

A summary of the potential sources of contamination are described in Table 4.

TABLE 4 SUMMARY OF POTENTIAL SOURCES OF CONTAMINATION

Potential Sources	Details
Former gas manufacturing process	Gas manufacturing processes that are believed to have been undertaken on-site include; • Coal carbonisation plant (CCP); • Complete gasification plant (CWGP); and • Oil Gas Plant (OGP). The manufacturing processes that occurred on site for almost 100 years created a variety of products/wastes. These wastes contained chemicals of concern to human health and the environment which were introduced to soil and groundwater. The potential pathways for these sources to impact identified receptors are discussed below.
Chemicals of Concern (CoC)	CoC include contaminants associated with the historical uses of the site. These include: TPH, BTEX, PAHs, heavy metals, sulphate, sulphide, cyanide and ammonia. Refer to section 3.2 and 3.3 for further details regarding the soil and groundwater contamination.

3.2 Soil contamination sources

3.2.1 Historical investigations (Golder 2004 and 2006)

The following main areas of soil contamination have been identified, based on Golder reports from 2004 and 2006:

- Soil within the Gasworks Park site was reported to contain elevated concentrations of Arsenic, BaP, total PAH, MAH, Cyanide and TPH:
  - arsenic concentrations were reported ranging from 5 mg/kg (GW16) to 550 mg/kg (GW13);
  - concentrations of BaP were reported ranging from 0.1 mg/kg (GA5) to 970 mg/kg (GW23);
  - concentrations of total PAH were reported ranging from 0.1 mg/kg (GW11) to 37,000 mg/kg (GW24);
  - concentrations of benzene were reported ranging from 21 mg/kg (GW24) to 1,400 mg/kg (GW23);
  - cyanide concentrations were reported ranging from 0.2 mg/kg (GW2 and GW5) to 1,400 mg/kg (GW24); and
  - TPH (C9 – C36) concentrations were reported ranging from 65 mg/kg (BH13) to 116,000 mg/kg (GW24);
- elevated contaminant concentrations were generally confined to fill material, which was encountered at up to 2.6 m BGL. Elevated concentrations of BaP and total PAH were reported in natural soil at depths up to 8.2 m BGL (south of the grassed area);
- soil sampling and analysis undertaken within the Southport site identified elevated concentrations of lead, cyanide, BaP, total PAH, TPH and benzene:
  - concentrations of BaP were reported ranging from 0.1 mg/kg (BH10) to 640 mg/kg (BH8);
  - concentrations of total PAH were reported ranging from 1.8 mg/kg (HA1 and GW3) to 11,278 mg/kg (BH8);
  - TPH (C_9 – C_{36}) concentrations were reported ranging from 84 mg/kg (HA2) to 47,800 mg/kg (BH11);
  - sulphide concentrations were reported ranging from 64 mg/kg (HA1) to 4,000 mg/kg (BH9);
  - cyanide concentrations were reported ranging from 5 mg/kg (GW5) to 4,700 mg/kg (BH11); and
  - lead concentrations were reported ranging from 5 mg/kg (BH5, BH11 and GW5)) to 600 mg/kg (BH11);
- elevated contaminant concentrations were confined in fill material, which was encountered at depths up to 1.4 m BGL across the Southport site. Highest contaminant concentrations were identified in boreholes drilled in the area of the former tar tank and purifiers (in the south western portion of the Southport site); and
- visual signs of contamination at the or near the surface including, the presence of coke, tar, bricks, glass and spent oxide pieces across the site.

The historical benzo(a)pyrene (BaP) and total polycyclic aromatic hydrocarbons (PAH) concentrations reported for are presented within Figures 4a to 4c.

For further details regarding detected historical site contamination, please refer to Golder Associates reports 2004b, 2006c and 2006d (Appendix A).

3.2.2 Most recent soil capping investigation (Environmental Earth Sciences 2011b)

Based on visual observations during the field program, the thin layer of brown loam and the yellow-orange sandy clays, where they occur, constitute the capping layer placed over the site as part of the historical redevelopment. The capping layer is generally at least 0.5m thick where the sandy clays occur on approximately half the site, but thins out to the brown loam layer across the outer edges of the site. The remainder of the site consists of the thin sandy gravel layer of the pathways, lain directly on top of impacted material, or is sealed beneath site buildings. However, the physical assessment of the capping layer has indicated that discrete exposed soil areas of the site contain less than the required 0.5m of capping.

The outcome of the soil capping investigation indicated variability of the historical soil capping layer, presence of elevated concentrations of polycyclic aromatic hydrocarbons (PAH), heavy metals and other associated CoC and the presence of gasworks waste within the top 0.5m of soil across the majority of the site in various lithologies.

The summary of exceedences and findings within the Gasworks Park has been detailed below:

- lead – two samples exceed HIL E criteria which is also the EIL criteria, with a maximum concentration of 6,720 mg/kg was noted for test-pit TP18 (0.7-0.8);
- arsenic – 17 samples exceeded EIL criteria;
- copper – one sample exceed EIL criteria;
- mercury – six samples exceed EIL criteria;
- nickel – three samples exceed EIL criteria;
- zinc – ten samples exceed EIL criteria;
- sulfate (NEPM) – four samples exceed EIL criteria which is also the criteria for protection of concrete structures (buildings), and an outlier maximum concentration of 14,300 mg/kg was noted for test-pit TP18 (0.7-0.8);
- sulfide – seven samples exceed EIL criteria, and an outlier maximum concentration of 12,044 mg/kg was noted for test-pit TP18 (0.7-0.8);
- cyanide – one sample exceed HIL E criteria with an outlier maximum concentration of 4,240 mg/kg in sample TP20 (0.8-0.9);
- TRH (>C_{10}-C_{16}) – two samples exceed HSL C (HIL E equivalent) criteria, with a maximum concentration of 8,230 mg/kg detected (test-pit TP7, 1.75-1.8m);
- TRH (>C_{16}-C_{34}) – 16 samples exceed HSL C (HIL E equivalent) criteria, with a maximum concentration of 29,500 mg/kg detected (test-pit TP7, 1.75-1.8m);
- TRH (C_{34}-C_{40}) – 12 samples exceed HSL C (HIL E equivalent) criteria, with a maximum concentration of 4,460 mg/kg detected (test-pit TP7 1.75-1.8);
- B(a)P – 54 samples exceed HIL E criteria and a maximum concentration of 1,040 mg/kg was reported for borehole BH11 (0.5-0.6m);

- naphthalene – two samples exceed HSL C (equivalent HIL E) with a maximum concentration of 6,600 mg/kg reported for borehole BH11 (0.5-0.6m);
- total PAH – 49 samples exceed HIL E criteria and a maximum concentration of 28,957 mg/kg was reported for borehole BH11 (0.5-0.6m);
- viscous tar was encountered in three sampling locations including:
  - Borehole BH13 (viscous tar observed with other pyrogenic waste at 0.9 m BGL);
  - Test-pit TP26 (minor amounts of viscous tar observed with other pyrogenic waste between 0.3 ~2.0 m BGL with impacts into natural material); and
  - Test-pit TP7 (solid tar mixed with other gasworks waste and rubble between 0.1-1.1 m BGL and semi-viscous tar encountered between 1.8-2.7 m BGL with discrete solid tar layer 1.9-2.0 m BGL);
- potentially perched water with a hydrocarbon sheen was encountered in test-pit TP10 at 2.4 metres;
- solid tar was encountered in the following sampling locations:
  - Borehole BH11 (mixed with other pyrogenic gasworks waste between 0.5-0.9 m BGL);
  - Test-pit TP6 (in a discrete layer between 0.8-1.1m BGL);
  - Test-pit TP7 (in a discrete layer between 0.1-1.1 mBGL); and
  - Test-pit TP11 (in a discrete layer between 1.4-1.6 m BGL);
- blue spent oxides were observed mixed with other fill and gasworks waste in five sampling locations including:
  - Borehole BH4 (0.1-0.4 m BGL);
  - Test-pit TP4 (0.35-0.6 m BGL);
  - Test-pit TP6 (1.1-1.8 m BGL);
  - Test-pit TP18 (0.4-2.0 m BGL); and
  - Test-pit TP20 (0.8-1.0 m BGL).

The summary of exceedences and findings within the SouthPort Nursing home has been detailed below:

- lead – three samples exceeded HIL A criteria and one sample exceeded EIL criteria;
- arsenic – one sample exceeded HIL A criteria and four samples exceeded EIL criteria;
- copper – three samples exceed EIL criteria;
- mercury – four samples exceed EIL criteria;
- nickel – one sample exceed EIL criteria;
- sulfate – three samples exceed EIL criteria which is also the criteria for protection of concrete structures (buildings);
- sulfide – three samples exceed EIL criteria;
- cyanide – two samples exceed HIL A criteria;
- B(a)P – 20 samples exceed HIL A criteria and a maximum concentration of 97.6 mg/kg was reported for borehole BH8 (0.0-0.1m);

- total PAH – 16 samples exceed HIL A criteria and a maximum concentration of 1,744 mg/kg was reported for borehole BH8 (0.0-0.1m);
- naphthalene – three samples exceed HSL-A for the vapour intrusion pathway, none for direct soil contact (soil ingestion, dust inhalation and dermal contact), with a maximum concentration of 28.9 mg/kg at borehole BH8 (0.0-0.1m);
- TRH >C_{10}-C_{16} – four samples exceed HSL-A for the vapour intrusion pathway, none for direct soil contact, with a maximum concentration of 480 mg/kg at borehole BH4 (0.2-0.3m);
- TRH >C_{16}-C_{34} – four samples exceed HSL-A for the direct soil contact pathway, with a maximum concentration of 4,880 mg/kg at borehole BH4 (0.2-0.3m); and
- TRH >C_{34} – one soil sample exceeds HSL-A for direct soil contact (1,640 mg/kg at borehole BH4, 0.2-0.3m).

Blue spent oxides were observed to be mixed with other fill and gasworks waste in borehole BH4 (0.1-0.4 m BGL). The BaP, PAH and TRH concentrations reported during the soil capping investigation are presented within Figures 5 to 12.

For further details regarding the most recent capping investigation, please refer to Environmental Earth Sciences, 2011b.

3.3 Groundwater Contamination sources

Investigations undertaken at the site (refer to Appendix A) have identified the following main areas of groundwater contamination.

3.3.1 From Historical Findings (Golders 2006 to 2007)

- Contamination with common gasworks chemicals, including heavy metals, ammonia, total cyanide, sulfate, total dissolved solids (TDS), PAHs, TPHs and monocyclic aromatic hydrocarbons (MAHs);
- the main sources of ammonia, TDS and sulfate in the groundwater appears to be in the north eastern portion of the site, whilst the main PAH and MAH sources appear to be in the south eastern and north eastern portion of the site;
- groundwater to the west and north west of Gasworks Park is contaminated with some heavy metals [arsenic (As), cobalt (Co), copper (Cu), lead (Pb), nickel, (Ni), zinc (Zn), selenium (Se), boron (B) and manganese (Mn)], sodium (Na), sulfate (SO42-), chloride (Cl), bicarbonate (HCO3) and total CN. Concentrations are generally consistent across the off-site wells to the east and north of Gasworks Park, potentially indicating background concentrations of the area;
- levels of pH were indicative of background concentrations and are not considered to be as a result of contamination at the site; and
- there were a variety of potential sources of groundwater contamination in the north-western portion of the Gasworks Park including Gasworks Park, the Alinta site, the former gasholder yard and laboratory site to the west of Pickles Street, and potentially other currently unidentified areas in the vicinity where gasworks fill which may have been placed as part of historical filling in the region.

For further detail regarding the detected historical groundwater contamination, please refer to Golder Associates, 2006a to 2006e and 2007.

3.3.2 From 2011 Groundwater Investigation

- Groundwater at the site is impacted with common gasworks contaminants, including heavy metals (primarily, As, Co, Cu, Pb and Zn), NH_4^+, CN, SO_4, PAHs, TPHs and MAHs. However, there is no evidence of either DNAPL or LNAPL existing on-site;
- the distribution of the groundwater contamination is consistent with the former gasworks infrastructure and the physical groundwater flow system described above, in which it would be expected that the full saturated thickness of the Brighton Group would have been impacted, particularly in the vicinity of the sewers. The greatest concentrations of SO_4^{2-}, NH_4^+, CN and many organics in 2011 were detected in monitoring wells screened at the base of the Brighton Group near the perimeter of the site in the vicinity of former gas purifiers towards the down gradient end of the flow system. This contamination is interpreted to have originated on site. The groundwater in the Brighton Group is not interpreted to have been significantly impacted by the upwelling of higher salinity groundwater via the underlying Older Volcanics in comparison to the impacts from the Gasworks site;
- the relatively low contaminant concentrations towards the centre of the site in comparison to the site perimeter could be due to less contamination originating from the central part of the site but may also reflect some flushing of the on-site flow system with less contaminated recharge since the site ceased to operate as a gasworks in 1971;
- as all the groundwater migrating from the site is captured by the sewers, all the contaminants dissolved in the groundwater are also captured by the sewers. Due to the proximity of the sewers to the site boundaries, for the most part, the contaminated groundwater from the site migrates directly to the sewers without passing beneath neighbouring properties. However, there is an area to the northeast of Richardson Street where there is a plume of NH_4^+ and SO_4^{2-} contamination, where the presence of elevated NH_4^+ could be a driver for groundwater remediation if found to be necessary, that migrates beneath up to 18 properties en route to the South Yarra Sewer Main beneath Bridport Street. Relatively high concentrations of CN have also been detected in groundwater samples from this area. Therefore, although the current groundwater flow direction is interpreted to be not across, but parallel, to Richardson Street, the Gasworks site is considered likely to be the original source of this area of groundwater contamination;
- elevated concentrations of PAHs (primarily BaP) were detected within newly installed groundwater wells in an area of very low hydraulic gradient in the northern part of the site, close to the Alinta Site. There is no identifiable source of these PAHs within this area, with the exception of buried waste. Based on the low hydraulic gradient, the likely source of PAH impacts (which is limited in its capacity to impact groundwater) and the insolubility of PAHs, it is considered unlikely that contaminated groundwater at Gasworks Park would migrate to the north west beneath the Alinta Site and pose a risk to off-site users; and
- the TDS results were reported higher within those wells located adjacent to sewers, suggesting that the seawater from the Bay was potentially migrating along the sewers and causing very high TDS values.

The summary of results for 2011 GME has been presented within Figure 13. For further detail regarding other results, please refer to Golder Associates, 2004b, 2006c and 2006d.

It should be noted that another round of groundwater sampling was undertaken on selected monitoring wells and the main objectives of this round of groundwater sampling are to evaluate the trends of contaminants of concern of selected elevated wells and to provide additional spatial information associated with the extent of groundwater contamination off-site.

In summary, the groundwater contamination conditions onsite and off-site are relatively stable (with slight increase or decrease) with some rise of contaminant concentrations (above background concentrations) within the NW and NE Wells but the long term trend of chemicals of concern were generally stable over the years and the dissolved contaminant plume is considered to be stable. In addition, as there are no known extraction wells used for groundwater Segment A2 beneficial uses located within the vicinity of NW and NE wells, the increase of contaminants of concern in some locations within the adjacent residential properties can be considered unlikely to pose un-acceptable risks to adjacent users (refer to Environmental Earth Sciences, 2014_v2 report for further details).

3.4 Potential receptors

The on-site contamination as well as contamination migrating off-site all has the potential to impact upon a variety of sensitive receptors.

The two main receptor groups relating to the site are the environment (ecological) and human (health), with artificial receptors also being considered.

3.4.1 Human users of the site

Given the site location and setting, along with the current and proposed future use, the following sensitive receptors may be exposed to contaminants via direct contact/ingestion (but are not necessarily limited to):

- park users (adults and young children) – potentially influenced by direct contact with soil, ingestion of on-site vegetation;
- maintenance and excavation workers (surface and sub-surface workers) – influenced by direct contact with soil; and
- residents (i.e. Southport aged-care residents and off-site residents) – potentially influenced by direct contact with soil, and ingestion of vegetation exposed to impacted soil.

3.4.2 Ecological receptors

Ecological receptors include any living organisms other than humans, the habitat which supports such organisms, or natural resources, which could be adversely affected by contamination released at or migrated from the site.

Given the site location, local setting and land uses, ecological receptors include (but are not necessarily limited to):

- vegetation growing on-site (native and introduced) – influenced directly by up-take of chemicals within soil;
- vegetation growing off-site (native and introduced) – potentially influenced by the use of groundwater for irrigation; and
- fauna (including native and introduced, and local and transitory including dogs) – influenced directly by soil contact and ingestion such as digging of soil onsite and consumption of the vegetation.

3.4.3 Adjacent site users

The site is generally surrounded with residential properties and few institutional buildings and therefore the sensitive human receptors to chemicals within groundwater and vapour include (but are not necessarily limited to):

- maintenance and excavation workers (surface and sub-surface workers) – by inhalation of vapour and contact with groundwater (extracted for potable use or other beneficial uses);
- residents - potentially influenced by inhalation of vapour and contact with groundwater (extracted for potable or domestic use such as filling up of swimming pool, irrigation or other protected beneficial uses); and
- students - potentially influenced by inhalation of vapour and contact with groundwater (extracted for potable use or other beneficial uses).

3.4.4 Buildings and structures

Buildings and structures at and around the site (which also represent sensitive receptors) include eleven commercial buildings on-site (i.e. bookshop, theatre and ceramics workshop, and walls around the site), the Southport Community Nursing Home and residential, commercial and light industrial properties adjacent to the site.

These buildings are considered receptors as sub-surface components (i.e. footings and foundations) will be in contact with soil. Soil which is acidic or corrosive may degrade concrete structures leading to collapse.

3.5 Potential Transport Mechanisms and Exposure Pathways

The CoC can potentially be transported and the receptors can be exposed via the following:

- groundwater migration / dermal contact and ingestion of contaminated groundwater;
- extraction of groundwater / dermal contact and ingestion of contaminated groundwater;
- dust and human or ecological interference to soil impacts / dermal contact / Ingestion of contaminated soil; and
- vapour migration / inhalation of vapours

Based on the assessment of the transport mechanisms and exposure pathways, the majority of the exposure pathways can be considered incomplete with the exception of direct contact/ingestion of soil in the longer term (refer to Sections 3.6.1 to 3.6.4).

Refer to Table 6 for the summary of potential transport mechanisms and exposure pathways to receptors.

3.5.1 Groundwater migration / Dermal contact and ingestion of contaminated groundwater

Regional groundwater flow in the basement Dargile Formation is towards Port Phillip Bay, therefore under natural hydraulic gradients, the groundwater flow direction would be expected to be towards the south to south west beneath the site. However, due to the surrounding sewer system(s) controlling local groundwater flow in the Brighton Group sediments, groundwater from beneath the site is captured and therefore the risk of impacted groundwater from Gasworks Park discharging to Port Phillip Bay can be considered unlikely.

3.5.2 Extraction of Groundwater / Dermal contact and ingestion of contaminated groundwater

The protected beneficial uses of the groundwater are outlined in the State Environment Protection Policy *Groundwaters of Victoria* (1997) for Segments A_2 and discussed in Section 6.1.7. Although the groundwater beneficial uses are precluded on-site (e.g. potable water supply, primary contact recreation, irrigation, domestic and stock water), this is not considered to be relevant as the site is currently being used as park and nursing home and no extraction bores will be installed for recreational purposes or other relevant beneficial uses.

There are 291 registered wells located within a 3 km radius of the site (refer to section 2.9.2 for further detail). However, based on the registered groundwater bore search, groundwater is not used in the area (<400m of the site) and is not likely to be used in the foreseeable future due to availability of municipal water supply. In addition, the groundwater use is also limited by low yield within the water bearing zones. As such, restricted groundwater use means that exposure pathways via groundwater consumption and contact can be considered unlikely.

3.5.3 Dust and human or ecological interference to soil impacts / Dermal Contact / Ingestion

Exposure to soil impacts (gasworks waste, tar, spent oxides, etc) and dust originating from expose surface onsite can be considered limited or acceptable in the short term as the site is currently managed by the ICMPs.

Given the wide distribution of contaminants on-site, variability of the historical soil capping layer thickness, presence of elevated concentrations of polycyclic aromatic hydrocarbons (PAH) and other CoCs, and presence of gasworks waste within the top 0.5m of soil across the majority of the site in various lithologies and recognising greater importance to the adverse effects of prolonged exposure of potential receptors (human and ecological including dogs) then this needs to be addressed to reduce the risk.

3.5.4 Vapour migration / Inhalation

As the site is to remain an open space park land, along with the limited soil capping layer (consisting of clay layer) and the majority of the detected contaminants of concern were semi-volatiles, this exposure can be considered unlikely for outdoor vapour migration.

In addition, detectable concentrations of indoor vapours measured at the site inside the buildings by Environmental Earth Sciences (refer to Environmental Earth Sciences 2012) were low and appeared largely due to indoor cross contaminating sources noted to be within the building such as paints, solvents, thinners, glues, resins etc. Only benzene, naphthalene and trimethylbenzene concentrations in three separate locations exceeded initial screening criteria, and only benzene exceeded the exposure adjusted criteria.

Environmental Earth Sciences considered that the concentrations were attributable to indoor sources rather than from as a result of gasworks waste at the site.

The vapour intrusion exposure pathway appeared to be mitigated by the following factors:

- building design, including ventilation, building height and subsurface penetrations;
- radial flow of impacted groundwater outwards away from buildings due to drawdown from sewers;
- the low likelihood of gasworks waste buried in soil beneath or in close proximity to original gasworks buildings; and

- the natural site setting with depth to groundwater greater than 7m in sandy clay soils.

Based on the results of the Indoor Air Quality Assessment, Environmental Earth Sciences consider that any sub-surface vapour intrusion at the site appears to be negligible and unlikely to result in a chronic unacceptable health risk to building users.

On this basis, remedial options and / or management systems are not considered necessary at this time to manage vapour intrusion into site buildings. This conclusion is provisional upon site land use and buildings remaining unaltered.

3.6 Qualitative measure of likelihood and consequence

The measures of likelihood and consequence are given in Table 5 and are described in Section 3.6.1 and 3.6.2.

3.6.1 Likelihood

- Almost certain is expected to occur in most circumstances;
- Likely: will probably occur in most circumstances;
- Possible: could occur;
- Unlikely: could occur but not expected; and
- Rare: occurs only in exceptional circumstances.

3.6.2 Consequence

- Catastrophic: death, toxic release off-site with detrimental effect, huge financial loss;
- Major: extensive injuries, loss of production capability, off-site release contained with outside assistance and little detrimental impact, major financial loss;
- Moderate: medical treatment required, on site release contained with outside assistance, high financial loss;
- Minor: first aid treatment, on site release immediately contained, medium financial loss; and
- Insignificant: no injuries, low financial loss, negligible environmental impact.

TABLE 5 RISK MATRIX

Consequence	Likelihood				
	1 – Almost Certain	2 – Likely	3 – Possible	4 – Unlikely	5 – Rare
1 – Catastrophic	1	2	3	4	5
2 – Major	2	4	6	8	10
3 – Moderate	3	6	9	12	15
4 – Minor	4	8	12	16	20
5 – Insignificant	5	10	15	20	25

TABLE 6 SUMMARY OF POTENTIAL TRANSPORT MECHANISMS AND EXPOSURE PATHWAYS TO RECEPTORS

Potential Receptors	Media	Transport Mechanisms	Exposure Pathway	Additional Comments	Exposure / Risk Classification (Short term)			Exposure / Risk Classification (Long term)		
					Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
Human users of the site	**Contaminated soil**	**Dust and interference of soil impacts** **Vapour migration**	**Direct contact / ingestion / inhalation of contaminated soil**	It should be noted that the proposed future use for the site is to remain 'open space park land' with little to no exposure to the underlying impacted fill material. It should be noted that the future use of Southport nursing home is currently being reviewed by the CoPP. The park users and nursing home residents are not expected to come into direct contact with the subsurface as part of daily activities as such activities do not include excavation below the ground surface. The exposure of the park users, maintenance and excavation works and nursing home residents to impacted soil and dust inhalation can be considered limited or acceptable in the short term. In the longer term, even though the risk can be considered low, given the variability of the historical soil capping layer thickness, presence of gasworks waste and CoCs associated with gasworks within the top 0.5m of soil across the majority of the site in various lithologies, the likelihood and consequence of prolong exposure to contaminated soil needs to be considered. This can be considered relevant to children due to potential pica behaviour.	4	4	Unlikely / Low Risk - 16	3	3	Possible / Low to Medium Risk - 9

Potential Receptors	Media	Transport Mechanisms	Exposure Pathway	Additional Comments	Exposure / Risk Classification (Short term)			Exposure / Risk Classification (Long term)		
					Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
	Contaminated groundwater	**Extraction of groundwater** **Vapour migration**	**Direct contact / ingestion / inhalation of vapours from contaminated groundwater**	Although the groundwater beneficial uses are precluded on-site (e.g. potable water supply, primary contact recreation, irrigation, domestic and stock water), this is not considered to be relevant as the site is currently being used as a park and nursing home and no extraction bores will be installed for recreational purposes or other relevant beneficial uses as it was controlled by CoPP and State of Victoria.	4	5	Unlikely / Low Risk - 20	4	5	Unlikely / Low Risk - 20
Ecological Receptors	**Contaminated soil**	**Dust and interference of soil impacts** **Vapour migration**	**Direct contact / ingestion / inhalation of contaminated soil**	Based on the current site setting and contamination, the risk to the identified ecological receptors can be considered acceptable. In general, the status of the existing plants/trees onsite has been able to withstand the current soil impacts with very few isolated stressed vegetation areas being noted. However, it should be noted that the isolated stressed vegetation could be attributed to a number of factors and not just because of the existing soil impacts onsite. In the longer term, even though the risk can be considered low, given the variability of the historical soil capping layer thickness, presence of gasworks waste and CoCs associated with gasworks within the top 0.5m of soil across the majority of the site in various lithologies, the likelihood and consequence of prolong exposure to contaminated soil needs to be considered. This can be considered relevant to dogs due to their digging behaviour.	4	4	Unlikely / Low Risk - 16	3	3	Possible / Low to Medium Risk (9)

Potential Receptors	Media	Transport Mechanisms	Exposure Pathway	Additional Comments	Exposure / Risk Classification (Short term)			Exposure / Risk Classification (Long term)		
					Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
Adjacent site users	**Contaminated groundwater**	**Extraction of groundwater for irrigation or stock water** **Groundwater migration to Port Phillip Bay** **Vapour Migration**	**Dermal contact and ingestion of contaminated groundwater**	Due to the surrounding sewer system(s) controlling local groundwater flow in the Brighton Group sediments, groundwater from beneath the site is captured and therefore the risk of impacted groundwater from Gasworks Park discharging to Port Phillip Bay can be considered unlikely. Due to the proximity of the sewers to the site boundaries, for the most part, the contaminated groundwater from the site migrates directly to the sewers without passing beneath neighbouring properties with the exception to north-eastern residential properties. However, based on the registered groundwater bore search, groundwater is not used in the area (<100m of the site) and is not likely to be used in the foreseeable future due to availability of municipal water supply. In addition, the groundwater use is also limited by low yield within the water bearing zones. As such, restricted groundwater use means that exposure pathways via groundwater consumption and contact can be considered unlikely.	4	4	Unlikely / Low Risk - 16	3	3	Possible/ Low to medium Risk - 9

Potential Receptors	Media	Transport Mechanisms	Exposure Pathway	Additional Comments	Exposure / Risk Classification (Short term)			Exposure / Risk Classification (Long term)		
					Likelihood	Consequence	Risk	Likelihood	Consequence	Risk
Buildings and Structures	**Contaminated Soil and Groundwater**	**Installation of concrete slabs and footings**	**Direct contact to contaminated soil and groundwater**	Based on the pH levels ranging from 4.5 to 8.0 units along with total sulphate concentrations over 20,000 mg/kg in selected locations, these could potentially affect the existing structures and building materials on-site. However, based on the conditions of current buildings and structures, it appeared unlikely that the current site contamination is affecting the existing buildings and structures. In the longer term, even though the risk can be considered low, given the variability of the historical soil capping layer thickness and presence of elevated pH and sulphate, the likelihood and consequence of prolong exposure to contaminated soil need to be considered by CoPC. Consideration should also be given to the selection of building materials and concrete compositions for future buildings and structures. In addition, due to the depth to groundwater (over 7 mBGS), it can be considered unlikely that the building footings will intersect the groundwater.	4	4	Unlikely / Low Risk - 16	3	3	Possible / Low to Medium Risk - 9

3.7 Risk screening

The findings (GHD, 2008) of the auditors '*screening risk assessment'* identified 50 medium risk scenarios (i.e. risk to beneficial uses of the site). The auditor based his determination of further works (i.e. investigation, management or clean up) to reduce the identified 50 medium risk to low or negligible risk.

In order to address these medium risk scenarios, Environmental Earth Sciences developed the scope of works to undertake the soil capping investigations, additional groundwater investigations and a vapour assessment in consultation with the auditor. Based on the outcome of the soil capping investigations, given the wide distribution of soil impacts at the site, variability of soil capping layer and presence of gasworks waste within the top 0.5m of soil across the majority of the site in various lithologies this RAP has been developed to mitigate those outstanding issues.

4 REMEDIATION STRATEGY OPTIONS

A range of soil and groundwater remediation options have been considered for the site. The options considered include only those which are proven to be effective on past remediation or related projects. The following sections review each of the soil and groundwater remediation options considered and outline the selection process used.

4.1 Rationale for Development of a Remediation Strategy

The physical assessment of the capping layer undertaken by Environmental Earth Sciences has indicated the following findings:

- variability of the historical soil capping layer;
- presence of elevated concentrations of polycyclic aromatic hydrocarbons (PAH), and
- presence of gasworks waste within the top 0.5m of soil across the majority of the site in various lithologies.

Given the distribution of contamination is widespread and thus visually identifying and delineating the areas of contamination can be considered difficult, therefore it is recommended that various remediation options should be considered.

The groundwater at the site is impacted with common gasworks contaminants, including heavy metals (primarily, As, Co, Cu, Pb and Zn), NH_3^+, CN, SO_4, PAHs, TPHs and MAHs. However, as most of the groundwater migrating from the site is captured by the sewers, which means most of the contaminants dissolved in the groundwater are also captured by the sewers. However, there is an area to the northeast of Richardson Street where there is a plume of NH_4^+ and SO_4^{2-} contamination that migrates beneath up to 18 properties en route to the South Yarra Sewer Main beneath Bridport Street. Relatively high concentrations of CN have also been detected in groundwater samples from this area. Therefore, consideration is also given on how to manage the groundwater impacts.

Due to the varying nature and distribution of the contaminant types in both soil and groundwater, an effective remediation approach for the site must be tailored towards the key impacted source materials or matrices, which include:

- impacted soil;
- general gasworks waste such as spent oxides, coke and liquid and solid tar. There is only expected to be a small quantity of viscous tar on-site in soil based on field observations to date; and
- impacted groundwater.

A discussion of remediation options for impacted soil and groundwater is provided below.

4.2 Soil Remediation Volumes

Based on the available data to date and the heterogeneity of the capping and the presence of general gasworks waste and impacts of soil on-site, the area of concern to be managed is estimated to be the whole site including the building footprints, approximately 3.21 ha (32,100 m^2) to an estimated maximum depth of 8mbgs, giving an estimated volume of 256,800 m^3.

4.3 Remediation Options for Impacted Soil

The potential list of remediation options associated with impacted soil is extensive. Consequently, only relevant remediation strategies that have been considered the following:

- institutional controls / do nothing;
- capping and Isolation;on-site treatment – bioremediation and/or thermal treatment;
- off-site treatment; and
- off-site landfill disposal – excavation and disposal.

The remediation option evaluation for impacted soil is further discussed Table 7.

TABLE 7 REMEDIATION OPTION EVALUATION FOR IMPACTED SOIL

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Institutional controls / do nothing	No remedial action taken Impacted soil and general waste left in-situ.	Lowest greenhouse emissions.	No short term remedial costs incurred. No operation and maintenance required. No capital investment required.	No disturbance to site required. Existing landscape and structures can all be retained. No odour or dust management is required.	Protective of human health including on-site workers and community near the site as long as the Contamination Management Plan is being complied with for short term only. Direct access to soil will not be restricted due to the widespread of contamination at the site. Not protective of human health including on-site workers and community near the site in the long term, given greater importance for adverse effects with prolong exposure. Inconsistent with community and regulatory expectations for remediation of the site. On-going liabilities including human health and the environment would remain. Potential ongoing groundwater, sewers and surface water contamination.	Potential for future liability (e.g EPA notices and potential health impacts to users / workers if exposed to unsafe levels for a long period of time	An ongoing management plan will need to be developed for site users and potential future excavation or maintenance requirements. Impacted material would remain on-site indefinitely.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Capping and Isolation	Soil capping and installation of other mitigation measures to restrict direct access to soil Impacted soil and general waste left in-situ.	Protective of human health including on-site workers and community near the site as long as the Contamination Management Plan is being complied with for both short term and long term. Direct access to soil will be restricted and can be isolated with the appropriate mitigation measures. Minimal greenhouse emissions.	Low to medium remedial costs incurred. Low degree of operation and maintenance intensity Low degree of capital investment.	Limited excavation is required. Trees with high retention values can be managed appropriately. Existing structures can all be retained. Limited disruption to site. Limited management (e.g. dust, noise and odour) is required. Park and Nursing Home will only be unusable for a short period of time. Less than 6 months to clean up the site. Minimal odour management is required during the remediation works.	Impacted material would remain on-site indefinitely. Potential ongoing groundwater and sewers contamination.	-	An ongoing management plan will need to be developed for site users and potential future excavation or maintenance requirements. Impacted material would remain on-site indefinitely. Limited to accessible areas only and therefore additional investigation may be required. Consideration of appropriate drainage system should be installed across the site. May increase truck traffic during the delivery of fill material.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Onsite treatment - Bioremediation	The contaminant (volatile and semi-volatile organic compounds, hydrocarbons and selected inorganics) is either destroyed or the associated hazard is reduced to an acceptable level. Excavation of impacted soil and general gasworks waste for on-site treatment. This treatment option will include the use of biological additives to enhance contaminant breakdown. Validation sampling to demonstrate the removal of impacted soil. Excavation de-watering and on-site treatment. Reinstatement of excavated areas with material validated as suitable for the intended land use.	Protective of human health including on-site workers and community near the site. Compliance with relevant State and local authority requirements following completion of the remedial works. Consistent with the EPA waste hierarchy, including recycling and treatment. Protective of the environment. Facilitate future development of the site. Ongoing groundwater, sewers and surface water contamination can be restricted	-	-	Limited effectiveness on the other contaminants encountered at the site such as heavy metals. A stronger scientific base is required for rational designing of process and success. Bioremediation methods depend on having the right microbes in the right place with the right environmental factors for degradation to occur. Some chemicals are not amenable to biodegradation (e.g. heavy metals). In some cases, microbial metabolism of contaminants may produce toxic metabolites.	Medium to High remedial costs incurred. Medium degree of operation and maintenance intensity. Medium degree of capital investment.	Major excavation is required. Existing landscape and structures will be disrupted and could lead to the demolition of the heritage buildings. Limited site space to bioremediate the soil onsite. The park and nursing home will be unusable for a long period of time. Odour and dust management required for on-site treatment will be very difficult in such close proximity to residential and institutional buildings. Unknown extent of excavation due to the heterogeneity of the soil impacts and general gasworks waste on-site and therefore this would require either remediating the whole site (to an estimated maximum depth of 8mBGS) or further assessment. May increase truck traffic during the delivery and removal of the required equipment. Between one and two years to clean up the site.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Onsite Treatment – In-situ Vacuum Enhanced Thermal Treatment	Thermal processes use heat to increase the volatility, to burn, decompose, destroy or melt the contaminants (applicable to all CoCs). It uses electrical resistance/electro magnetic/fiber optic/radio frequency heating or hot air/steam injection to increase the volatilization rate of semi-volatile contaminants and facilitate their extraction. In effect. The process uses a combination of soil heating processes to enhance soil vapour extraction (SVE). A thermal treatment area is usually covered with an impermeable surface cover (such as concrete, asphalt, or a heavy-duty tarp) to keep the heat and steam underground. Such seals also help prevent the release of chemical vapours to the air. In-situ validation sampling to	Protective of human health including on-site workers and community near the site. Compliance with relevant State and local authority requirements following completion of the remedial works. Consistent with the EPA waste hierarchy, including recycling and treatment. Consistent with community and regulatory expectations of minimal impacts. Protective of the environment. Facilitate future development of the site.	–	No ongoing management is required. Limited disruption to site to install the thermal wells Park and Nursing Home will only be unusable for a short period of time. This treatment option can reach contamination deep underground or beneath buildings, which would otherwise be difficult or costly to dig up to treat above ground. Less than one year to clean up the site.	Highest greenhouse emissions (similar to Ex-situ Thermal desorption) Is highly dependent upon the specific soil and chemical properties of the contaminated media Given the heterogeneity of the soil capping onsite and presence of general gasworks waste across various lithologies, this may result in uneven delivery of airflow as part of the thermal process into the ground. Performance in extracting certain contaminants varies depending upon the maximum temperature achieved in the process selected, Hot air injection has limitations due to low heat capacity of air. Soil that is tight or has high moisture content has a reduced permeability to air and requires more energy to increase vacuum and temperature.	High to very high remedial costs incurred. High degree of operation and maintenance intensity. High degree of capital investment.	Limited site space to set-up the thermal treatment unit. Existing landscape and structures will be disrupted and could lead to the demolition of the heritage buildings. Regular collection of air samples is required to make sure that vapours are being captured. It would require the use of drilling equipment and other heavy machinery to install electrodes and to collect and treat vapours. It would require the installation of vapour treatment system. Vapour and odour management required for on-site treatment will be very difficult in such close proximity to residential and institutional buildings. May increase truck traffic during the delivery and removal of equipment. A potential explosion hazard exists from concentrated fumes released from the vacuum unit.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Onsite Treatment – Ex-situ Thermal Desorption	Thermal processes use heat to increase the volatility, to burn, decompose, destroy or melt the contaminants (applicable to all CoCs). The volatilised contaminants are then either collected or thermally destroyed. A thermal desorption system therefore has two major components; the desorber itself and the offgas treatment system.	Protective of human health including on-site workers and community near the site. Compliance with relevant State and local authority requirements following completion of the remedial works. Consistent with the EPA waste hierarchy, including recycling and treatment. Consistent with community and regulatory expectations of minimal impacts. Protective of the environment. Facilitate future development of the site.	–	No ongoing management is required. Less than one year to clean up the site.	Highest greenhouse emissions (similar to In-situ Thermal treatment.). Is highly dependent upon the specific soil and chemical properties of the contaminated media (soil contains a lot of clay, organic material, which causes contaminants to stick to the soil and not evaporates easily).	High to very high remedial costs incurred. High degree of operation and maintenance intensity. High to very high degree of capital investment.	Major excavation is required. Limited site space to set-up the thermal desorption unit. Existing landscape and structures will be disrupted and could lead to the demolition of the heritage buildings. Regular collection of air samples is required to make sure that vapours are being captured. Vapour, odour and dust management required for on-site treatment will be very difficult in such close proximity to residential and institutional buildings. Unknown extent of excavation due to the heterogeneity of the soil impacts and general gasworks waste on-site and therefore this would require either remediating the whole site (to an estimated maximum depth of 8mBGS) or f further assessment. May increase truck traffic during the delivery and removal of the required equipment. A potential explosion hazard exists from concentrated fumes released from the off-gas system.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Off-site treatment	The contaminant is either destroyed or the associated hazard is reduced to an acceptable level off-site (applicable to all CoCs). It can be treated either via bioremediation or thermal treatment. Excavation of impacted soil and general gasworks waste for off-site treatment. Validation sampling to demonstrate the removal of impacted soil. Excavation de-watering and on-site treatment. Reinstatement of excavated areas with material validated as suitable for the intended land use.	Protective of human health including on-site workers and community near the site. Offsite treatment can be successfully achieved at an appropriate facility with less community odour issues than if treatment was undertaken on site. Compliance with relevant State and local authority requirements following completion of the remedial works Protective of the environment. Facilitate future development of the site. Ongoing groundwater, sewers and surface water contamination can be restricted	No onsite operation and maintenance required. No onsite capital investment required.	No ongoing management is required. Park and Nursing Home will only be unusable for a short period of time. Less than 6 months to clean up the site.		High to very high remedial costs incurred.	Major excavation is required. Existing landscape and structures will be disrupted. Odour, vapour and dust management required during the excavation works will be very difficult in such close proximity to residential and institutional buildings. Unknown extent of excavation due to the heterogeneity of the capping, soil impacts and general gasworks waste on-site and therefore this would require either remediating the whole site or may require further soil investigation. May increase truck traffic to transport contaminated soil for a short period of time.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Off-site disposal	Removal of contaminated soil to a licensed landfill or facility. Validation sampling to demonstrate the conditions of the residual soil impact. Reinstatement of excavated areas with material validated as suitable for the intended land use	Protective of human health including on-site workers and community near the site. Protective of the environment onsite. Facilitate future development of the site. Ongoing groundwater, sewers and surface water contamination can be restricted	No onsite operation and maintenance required. No onsite capital investment required.	Generally the same logistical benefits as onsite or off-site treatment options as the impacted soil will have to be treated prior to disposal to a licensed facility or landfill. Less than 6 months to clean up the site.	This method of remediation was considered the lowest hierarchy of VIC EPA preferred waste management. Based on the soil investigation results, for off-site disposal purposes, the impacted soil to be excavated onsite as per Industrial Waste Resource Guidelines 621 (IWRG 621 – Soil Hazard Categorisation and Management) is classified as Category A contaminated soil and therefore it cannot be disposed off-site without undertaking either an onsite or off-site treatment first to reduce the classification down to Category C or B contaminated soil.	Very high remedial cost incurred	Generally the same logistical issues as onsite or off-site treatment options as the impacted soil will have to be treated prior to disposal to a licensed facility or landfill.

A summary of the ratings for each technology is presented as a remediation technology review matrix (RTRM) in **Table 8**, including an assessment of:

- protective of human health and environment onsite;
- reliability and maintainability
- logistically viable; and
- operational cost.

A ranking (1 to 6) was assigned to each remediation technology with a ranking of 1 if rated highly compliance in the adopted assessment criteria with minimal reservations or additional controls required as part of the implementation. In addition, the advantages and disadvantages of each remediation option have also been considered in the ranking.

TABLE 8 REMEDIATION TECHNOLOGY REVIEW MATRIX (RTRM)

Remediation Technologies	Ranking	Protective of human health and environment onsite	Reliability and Maintainability	Logistically viable	Operational Cost
Capping and Isolation	1 (highest compliance in the assessment criteria with the lowest operational cost and lowest disturbance to the site)	Yes (it can provide an acceptable outcome by restricting the direct access to the residual soil/gasworks waste onsite)	Yes (provided the CMP will be complied with)	Yes	Low to medium
Institutional controls / do nothing	6 (not compliant with the assessment criteria and therefore would not require further consideration)	No	Not applicable	Not applicable	None
Onsite treatment - Bioremediation	3 (compliance with the adopted criteria with moderate operational cost but with limited effectiveness to in-organics)	Yes (provided in can be carried out in a safe and acceptable manner)	Yes (after treatment no further maintenance is required)	Yes	Medium to high
Onsite Treatment – In-situ/Ex-situ Thermal Treatment	2 (compliance with the adopted criteria with high to very high operational cost but should be able to treat a wider range of contaminants)	Yes (provided in can be carried out in a safe and acceptable manner)	Yes (after treatment no further maintenance is required)	Yes	High to very high

Remediation Technologies	Ranking	Protective of human health and environment onsite	Reliability and Maintainability	Logistically viable	Operational Cost
Off-site treatment	4 (compliance with the adopted criteria with high to very high operational cost)	Yes (provided in can be carried out in a safe and acceptable manner)	Yes (after the removal of contaminated soil/gasworks waste onsite, no further maintenance is required)	Yes	High to very high
Off-site disposal	5 (compliance with the adopted criteria with very high operational cost. In addition, it needs to be combined with other remediation options prior to disposal)	Yes (provided in can be carried out in a safe and acceptable manner)	Yes (after the removal of contaminated soil/gasworks waste onsite, no further maintenance is required)	Yes (only in combination with onsite or off-site treatment)	Very high

Based on our assessment detailed above, capping and isolation remediation option (rated 1) is recommended to be the most practical way of managing the soil onsite.

It should be noted that the recommended remediation option will not treat the residual contamination onsite and hence it could continue to be a potential source of groundwater impact. However, the potential risks to human health and ecological receptors can be reduced to an acceptable level by mitigating direct contact to future users.

The following management measures require consideration during the implementation of the selected remediation option:

- installation of appropriate drains across the site to direct the surface water onto the appropriate drainage system;
- minimal odour management of general gasworks waste or impacted soil if excavation is necessary;
- installation of dust suppression or hessian dust control within the site boundaries;
- fill material to be used for capping should be delivered onsite prior to commencing with the limited excavation (if necessary) as part of the capping and isolation remediation option; and
- a pre-start survey of the existing site condition and structures should be undertaken to determine which areas of the site where the implementation of 0.5m capping will be difficult and impractical and therefore other isolation mitigation measures (refer to Section 5.3.3) will be used to limit exposure.

4.4 Groundwater Remediation Area of Concern

The groundwater on-site and off-site to the north east is contaminated with former gasworks associated chemicals of concern. Therefore if groundwater remediation is required consideration should be given to both on-site and off-site north-eastern wells.

4.5 Remediation options for impacted groundwater

A number of active methods are available for further clean-up of the dissolved groundwater contaminants onsite and off-site (heavy metals, ammonia, total cyanide, sulphate, TDS, PAHs, TPHs and MAHs), including pump and treat, engineering controls, air sparging, multiphase extraction (site dedicated or mobile) and monitored natural attenuation (MNA).

The review of options for the remediation of impacted groundwater at the site has considered the following:

- no action / monitored natural attenuation;
- physical barrier;
- enhanced bioremediation;
- air sparging or air stripping
- dual Phase Extraction;
- advanced oxidation;
- chemical oxidation; and
- chemical fixation.

The remediation option evaluation for impacted groundwater is further discussed in Table 9.

TABLE 9 GROUNDWATER TREATMENT OPTION EVALUATION

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
No action / Monitored Natural Attenuation (MNA)	No remedial action taken. Impacted groundwater will be left in-situ. Natural attenuation makes use of natural processes to contain the spread of contamination in the groundwater and reduce the concentration and amount of pollutants over time.	No potential impacts related to the remediation of the site. Based on the groundwater investigation results, in most cases, the adjacent sewers around the site limits the migration of groundwater impact off-site except to the north-eastern residential properties. Protective of human health including on-site workers and community near the site and environment as long as the sewers adjacent the site will continue to operate and the extraction of groundwater can be controlled (groundwater is not used in the area (<400m of the site) and is not likely to be used in the foreseeable future due to availability of municipal water supply. In addition, the groundwater use is also limited by low yield within the water bearing zones). Protective of the environment, as all the groundwater flowing from the site is captured by the sewerage system, it is ultimately pumped to the Werribee Treatment Plant including the groundwater migrating to the north-eastern residential properties as it will eventually be captured by the South Yarra Sewer Main. No waste residues to dispose of. Either removes or reduces liability depending on targets set.	No active remedial costs incurred. No capital investment required. Low operation and maintenance required. The operation, maintenance and capital investment for the sewers will be the water authority responsibility.	Limited site and adjacent properties disturbance during the ongoing groundwater sampling Existing landscape and structures can all be retained. Can be done for both on-site or offsite.	Lack of control over the condition of the sewers over time. Potential ongoing environmental impact.	–	Ongoing groundwater monitoring under the Deed of Agreement. Consideration of Groundwater Quality Management Plan (GQMP) to check the groundwater trend over time, as this is an essential component of MNA. Consideration of Groundwater Quality Restricted Use Zone to manage the impacted groundwater and restrict access in the future. Extended timeframe likely required until contaminant concentrations reach an acceptable level (>20 years) Contaminants may further migrate before they are degraded. cannot be determined as the level of effectiveness will be dependent on site conditions and design application.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Physical Barrier	Physical barriers are used to contain contaminated groundwater or divert contaminated groundwater and/or provide a barrier for the ground water treatment system. In addition to the existing sewers adjacent to the site, a physical barrier will be installed along Richardson Street to prevent the migration of CoCs to the north-eastern residential properties.	Protective of human health including on-site workers and community near the site and environment as long as the sewers adjacent the site will continue to operate and the extraction of groundwater can be controlled. Protective of the environment, as all the groundwater flowing from the site is captured by the sewerage system and the proposed physical barrier along Richardson Street will prevent the groundwater impacts to further migrate to the north-eastern residential properties. Ongoing groundwater impact can be restricted onsite and to adjacent sewers.	The operation, maintenance and capital investment for the sewers will be the water authority responsibility.	Existing site landscape and structures can all be retained.	Lack of control over the condition of the sewers over time. Potential ongoing environmental impact.	High remedial cost incurred. High degree of capital investment, operation and maintenance requirement to install the physical barrier.	Major excavation is required along Richardson Street to install the physical barrier. Presence of underground utilities along Richardson Street would restrict the installation of physical barriers Ongoing groundwater monitoring under the Deed of Agreement. Consideration of Groundwater Quality Management Plan (GQMP) to check the groundwater trend over time. Consideration of Groundwater Quality Restricted Use Zone to manage the impacted groundwater and restrict access onsite in the future. Extended timeframe likely required until contaminant concentrations reach an acceptable level (>20 years)
Enhanced Bioremediation	Biological degradation of organic contaminants (VOC's including MAH's, SVOCs including TPH and PAHs, inorganics such as ammonia, nitrate, sulphate and selected heavy metals) aided by the introduction of nutrients and oxygen.	Protective of Environment and human health as long as it's combined with other remediation techniques to treat heavy metals. Returns waste to reusable product by breaking down organic contaminants. Either removes or reduces liability depending on targets set. The presence of nitrate, sulphate, ferrous ion can also be used as electron acceptors.	–	Can be done for both on-site or offsite using a mobile unit system. Limited site and adjacent properties disturbance.	This technology needs to be combined with other remediation options to treat inorganic contaminants. May require introduction of substances (i.e. nutrients) into aquifer. Difficult to control and maintain effective treatment including the difficulty in distributing the nutrients into the aquifer. The creation of transformation products that may be more toxic than the	Medium remedial cost incurred Medium degree of capital investment, operation and maintenance requirement.	Will have to be combined with other remediation techniques to treat other heavy metals. Extended timeframe likely to be required until contaminant concentrations reach an acceptable level (>10 years) Consideration of Groundwater Quality Management Plan (GQMP) to check the groundwater trend over time. Consideration of Groundwater Quality Restricted Use Zone to manage the impacted groundwater and restrict access in the future.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Enhanced Bioremediation					original contaminants. May not work if nutrient cycling not achieved. Difficulty to test efficacy in short term via pilot trial. Chance that subsurface conditions will not support natural attenuation as long as necessary.		Clean up time cannot be determined as the level of effectiveness will be dependent on site conditions and design application.
Dual Phase Extraction	It removes contaminants (VOC's including MAH's, SVOCs including TPH and PAHs and inorganics such as ammonia, nitrate, sulphate and heavy metals) from above and below the water table using a combination of a submersible pump and a vacuum system and then the treated water can be re-injected back into the aquifer or discharged into the adjacent sewers.	Protective of Environment and human health. Can treat dissolved and phase separated organics and inorganics and vapours using appropriate filtering media Can hydraulically control the groundwater inferred flow direction. Ongoing sewers and groundwater contamination can be restricted.	-	Can be done for both on-site or offsite using a mobile unit system. Limited site and adjacent properties disturbance.	Effectiveness depended on site geology and contaminant characteristics.	High remedial cost incurred. High degree of capital investment, operation and maintenance requirement.	Dual phase extraction requires both water treatment and vapour treatment. Due to widespread of contaminants of concern across the site, the management of this treatment option will be very difficult. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. Between 3 and 10 years to clean up the site.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Pump and Treat System	It removes contaminants (VOC's including MAH's, SVOCs including TPH and PAHs and inorganics such as ammonia, nitrate, sulphate and heavy metals) from below the water table using a submersible pump and then the treated water can be re-injected back into the aquifer or discharged into the adjacent sewers.	Protective of Environment and human health. Can treat dissolved and phase separated organics and inorganics using appropriate filtering media. Can hydraulically control the groundwater inferred flow direction. Ongoing sewers and groundwater contamination can be restricted.	-	Can be done for both on-site or offsite using a mobile unit system. Limited site and adjacent properties disturbance.	Effectiveness depended on site geology and contaminant characteristics.	Medium to high remedial cost incurred. Medium to high degree of capital investment, operation and maintenance requirement.	Due to widespread of contaminants of concern across the site, the management of this treatment option will be very difficult. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. Between 3 and 10 years to clean up the site.
Air Sparging	Injecting air into a screened well, by increasing the dissolved oxygen and at the same time can assist in transferring dissolved phase to vapour phase by the introduction of air bubbles, where they rise and vapours are drawn off and treated by another technology.	Protective of Environment and human health as long as it's combined with other remediation techniques to treat heavy metals.	-	Can be done for both on-site or offsite using a mobile unit system. Limited site and adjacent properties disturbance.	Applicable to organic contaminants and selected inorganics such as ammonia , nitrate, sulphate, iron and manganese. This technology needs to be combined with other remediation options to treat the remainder of the inorganics.	Medium remedial cost incurred. Medium degree of capital investment, operation and maintenance requirement.	Will have to be combined with other remediation techniques to treat the remainder of the in-organics. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. More than 10 years to clean up the site.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Air/steam stripping	Pump groundwater to column where it is dropped as a fine mist to convert the contaminants to gas. Process encouraged by use of steam to raise temperature.	Partially protective of Environment and human health.	-	Can be done for both on-site or offsite using a mobile unit system. Limited site and adjacent properties disturbance.	Two waste streams to deal with. Not suitable for contaminants with boiling points well above 100^{o}C. Not very successful for low volatility compounds. Applicable to organic contaminants and selected inorganics such as ammonia , nitrate, sulphate, iron and manganese. This technology needs to be combined with other remediation options to treat the remainder of the inorganics.	Medium remedial cost incurred. Medium degree of capital investment, operation and maintenance requirement.	Will have to be combined with other remediation techniques. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. More than 10 years to clean up the site.
Advanced Oxidation	UV/oxidation is a destruction process that oxidizes organic and explosive constituents in contaminated groundwater by the addition of strong oxidizers and irradiation with ultraviolet light.	Protective of Environment and human health. Effective for all organic contaminants (VOC's and SVOC's) and selected inorganics such as ammonia, nitrate and heavy metals affecting the site.	-	-		Very high remedial cost incurred. Very high degree of capital investment, operation and maintenance requirement.	UV and ozone treatment are not readily available in Australia. May be risky to apply off-site due to potential exothermic chemical reactions. Moderate site and adjacent properties disturbance. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. Between 3 and10 years to clean up the site.

Treatment Option	Description	Advantages			Disadvantages		
		Technical	Financial	Logistical	Technical	Financial	Logistical
Chemical Oxidation	Pump groundwater to tank where dosed with chemical oxidising agent (e.g. potassium permanganate) and then re-injected back into the aquifer. Oxidising agent converts contaminants into innocuous common naturally occurring compounds	Protective of Environment and human health as long as it's combined with other remediation techniques to treat inorganic contaminants such as nitrate, sulphate, ammonia and heavy metals. Effective for all organic contaminants (VOC's and SVOC's) affecting the site.	-	Can only be done onsite using a mobile unit system. Shorter time frame when compared with other options.	Precipitates can be produced which can block pores in the aquifer. Applicable to organic contaminants only. This technology needs to be combined with other remediation options to treat all inorganics such as ammonia, nitrate, sulphate and heavy metals	Very high remedial cost incurred. Very high degree of capital investment, operation and maintenance requirement.	Will have to be combined with other remediation techniques to treat all inorganics (ammonia, nitrate, sulphate and heavy metals). Requirement for dangerous goods handling. Can be difficult to control. Will have to be combined with other remediation techniques. Moderate site and adjacent properties disturbance. May be risky to apply off-site due to potential exothermic chemical reactions. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. Between 3 and10 years to clean up the site.
Chemical Fixation	The product (with carbon and zero valent ion) is mixed with water to create slurry and is delivered through direct push injection tooling to the target interval.	Protective of Environment and human health. Treatment of dissolved metals in groundwater involves sequestration as solid metal species by means of reductive precipitation and adsorption onto the iron oxidation products.	-	Can be done for both on-site or offsite using a mobile unit system or direct push drilling unit.	Only applicable to heavy metals to reduce toxicity and leachability. This technology needs to be combined with other remediation options to treat organic and other inorganic contaminants.	Medium to High remedial cost incurred. Medium to high degree of capital investment, operation and maintenance requirement.	Will have to be combined with other remediation techniques Moderate site and adjacent properties disturbance. It would require the use of drilling equipment to inject the product. Consideration of Groundwater Quality Management Plan (GQMP) to check remediation progress. Between 3 and10 years to clean up the site.

Numerous remedial technologies evaluated as part of the initial screening process are not considered suitable for further detailed assessment on the basis that they are not suitable for the contaminants of concern, have a very high cost in comparison with other technologies, or are impractical in the context of addressing contamination in off-site areas. Those technologies which are considered to be potentially suitable were further evaluated in Table 9.

A summary of the ratings for each technology is presented as a remediation technology review matrix (RTRM) in **Table 10**, including an assessment of:

- protective of human health onsite and off-site;
- protective of environment and other protected beneficial uses (Segment A2);
- capacity to achieve contaminant mass reduction over time;
- logistical viable; and
- operational cost.

A ranking (1 to 6) was assigned to each remediation technology with a ranking of 1 if rated highly in the adopted assessment criteria with minimal reservations or additional controls required as part of the implementation.

TABLE 10 REMEDIATION TECHNOLOGY REVIEW MATRIX (RTRM)

Remediation Technologies	Rank	Protective of human health onsite and off-site	Protective of environment and other protected beneficial uses	Capacity to achieve contaminant mass reduction over time	Logistically viable	Operational Cost
No Action / Monitored Natural Attenuation	1	Yes (as long as the sewers adjacent the site will continue to operate and the extraction of groundwater can be controlled)	Yes (potential on-going groundwater impact both onsite and off-site, however it is expected all groundwater will discharge to the adjacent sewers)	No (assuming that on-going impact from soil impacts will continue over time)	Yes (on-going groundwater sampling can be undertaken in both onsite and off-site wells)	Low
Physical Barrier	8	Yes (as long as the sewers adjacent the site will continue to operate and the extraction of groundwater can be controlled)	Yes (potential on-going groundwater impact onsite, however it is expected all groundwater will be discharged to the adjacent sewers)	No (assuming that on-going impact from the soil impacts will continue over time	No (the presence of underground utilities along Richardson Street would restrict the installation of physical barriers)	High
Enhanced Bioremediation	3	Yes (when combined with other remediation techniques to treat in-organics)	Yes (when combined with other remediation techniques to treat in-organics)	Yes (can reduce organics over time)	Yes (can be done both onsite and off-site using a mobile unit system)	Medium

Remediation Technologies	Rank	Protective of human health onsite and off-site	Protective of environment and other protected beneficial uses	Capacity to achieve contaminant mass reduction over time	Logistically viable	Operational Cost
Dual Phase Extraction	5	Yes (can treat both organics and inorganics using appropriate filtering system)	Yes (can treat both organics and inorganics using appropriate filtering system)	Yes (can reduce organics and in-organics over time)	Yes (can be done in both onsite and off-site using a mobile unit system)	High
Pump and Treat	4	Yes (can treat both organics and inorganics using appropriate filtering system)	Yes (can treat dissolved and phase separated organics and inorganics using appropriate filtering media)	Yes (can reduce organics and in-organics over time)	Yes (can be done in both onsite and off-site using a mobile unit system)	Medium to high
Air Sparging or Air Stripping	2	Yes (when combined with other remediation techniques to treat in-organics)	Yes (when combined with other remediation techniques to treat in-organics)	Yes(can reduce organics over time)	Yes (can be done in both onsite and off-site using a mobile unit system)	Medium
Advanced Oxidation	9	Yes (effective for all organic contaminants (VOC's and SVOC's) and selected inorganics such as ammonia, nitrate and heavy metals affecting the site)	Yes (can treat organics and selected in-organics relevant to the site)	Yes (can reduce organics and in-organics over time)	Yes (however, may be risky to apply off-site due to potential exothermic chemical reactions)	Very High
Chemical Oxidation	8	Yes (when combined with other remediation techniques to treat in-organics)	Yes (when combined with other remediation techniques to treat in-organics)	Yes(can reduce organics over time)	Yes (however, may be risky to apply off-site due to potential exothermic chemical reactions).	Very High
Chemical Fixation	7	Yes (when combined with other remediation techniques to treat organics)	Yes (when combined with other remediation techniques to treat organics)	No (can only reduce toxicity and leachability)	Yes (can be done for both on-site or offsite using a mobile unit system or direct push drilling unit)	Medium to high

Based on our assessment detailed above, the practical way of managing the groundwater impacts is not to undertake any active or passive groundwater remediation other than the implementation of a regular groundwater monitoring as an essential component of do nothing or monitored natural attenuation option.

Environmental Earth Sciences considers that the risk posed by the current groundwater status is low and the implementation of active or *in-situ* remediation of groundwater at the site is considered to be impracticable based on the following reasons:

- given the fact that the majority of the groundwater discharging from the site is captured via the surrounding sewer network (acting as a physical barrier) except to the east of the site;
- low likelihood of use of the groundwater for any beneficial uses due to the availability of reticulated mains water; and
- low yield of the Brighton group aquifer.

Despite the low likelihood of use of the groundwater for the relevant extractive beneficial uses (potable water supply, irrigation, stock watering, industrial water use and primary contact recreation) in the residential area to the north east of the site, this potential beneficial use cannot be discounted in this area and therefore implementing a Groundwater Quality Management Plan (GQMP) is recommended.

The objectives of the Groundwater Quality Management Plan are to:

- ensure that residual polluted groundwater is managed to prevent unacceptable impacts on human health and the environment;
- to provide a mechanism for periodic review of groundwater database to confirm bore network surrounding the site;
- to provide a mechanism for periodic review of inferred groundwater flow; and
- to provide a mechanism for periodic review of polluted groundwater to confirm the trend of the groundwater contamination remains stable or decreasing.

In addition to the GQMP, the implementation of the contingency plan will be adopted if any of the following triggers are identified:

Trigger A: an increasing trend of a contaminant concentration (using statistical method such as the Mann-Kendall non-parametric test) over an 18-month period and observed to be above the risk based criteria.

Trigger B: any significant change in the nature of the contamination as identified in previous reports.

Trigger C: any identified changes in the groundwater flow direction as determined in previous investigations relevant to the site.

Trigger D: a trend that indicates a significant reduction in the effectiveness of on-going natural attenuation (geo-chemical evolution) processes.

Trigger E: a change to the potentially exposed receptors or their assessed risk, such as a change in surrounding land-use or installation of a down-gradient borehole for extraction purposes.

Initially, if any trigger is identified, the reliability of the data will be reviewed, which may consist of a review of sampling and laboratory procedures and QA/QC procedures to ascertain whether the trigger is not an artefact of uncertainties in measurements. This will initially be conducted by the Consultant and provided to the Auditor for review. A repeat of the measurement may be required to assess the reliability of the data, which may include re-sampling or re-analysis of the original sample by the laboratory (if holding times are not exceeded).

Second, if the trigger exceedance is confirmed, contingency measures will be implemented. The contingency measures will be further discussed in the GQMP to be prepared upon completion of the next round of groundwater sampling.

5 REMEDIATION WORKS AND PROCEDURES

This section of the RAP provides an outline of the work procedures to be implemented during the implementation of the capping and isolation remediation works. Relevant management plans and documentation associated with these works will be prepared separately to the remediation works documentation.

Detailed work method statements with the proposed remediation works will be prepared by the remediation contractor as part of the remediation program.

5.1 Remediation Timeframe

The timeframe for the proposed on-site remediation works is approximately five months. This timeframe incorporates:

- one month allowance for initial site establishment, mobilisation, surveying, marking and staking of areas to be capped or isolated;
- three months for the capping, relocation, backfilling and re-instatement works; and
- one month for the additional soil investigation (if required) and demobilisation.

It should be noted that discussion with EPA regarding the possibility of a GQRUZ and the time to prepare all the necessary reports before and after remediation are not included in the remediation timeframe.

5.2 General Operational Details

5.2.1 Working Hours

Working hours for the site remediation works will be:

- Mondays to Fridays, 7:00 am to 5:00 pm; and
- Weekends and Public Holidays only as approved by CoPP; and
- If it is necessary to work outside these hours, local residents should be notified.

5.2.2 Site Facilities

Portable structures will need to be brought to site for use as site offices, storage and decontamination facilities.

5.3 Remediation Strategy

5.3.1 Preliminary tasks and preparation

The preliminary tasks and preparation include the following:

- preparation of a Safe Work Method Statement (SWMS), OH&S plan and traffic management plans (if required);
- seek endorsement of the RAP, including supporting documentation and management plans to VIC Environment Protection Authority (EPA) and the appointed auditor, Peter Nadebaum of GHD Pty Ltd;
- undertake a pre-start survey of the site, followed by preparation of a detailed plan showing the mitigation measures to be applied;
- seek endorsement of the detailed plan by the appointed auditor;
- all groundwater bores will be clearly marked out and labelled appropriately and will have to be extended if required before the commencement of the remediation works;
- all services within the remediation area will be disconnected, capped and made safe;
- undertake all necessary searches such as dial-before-you-dig (DBYD) and service location; and
- undertake an assessment of the current boundary walls to confirm the structural integrity and/or to identify what mitigation measure can be applied.

5.3.2 Site establishment

The site establishment will include the following:

- security fencing will be erected around the site;
- connections to the appropriate utilities will be established, i.e. electricity, water, sewer, communications;
- existing infrastructure such as light poles and other structures will be dismantled and removed from site;
- remediation exclusion and transition zones will be established by appropriate barriers/fencing to ensure that “contaminated” areas will be separated from “clean” areas;
- initial environmental and safety controls will be set up including shade cloth around the temporary fencing and signage. Other environmental controls including surface water control bunding (if required), truck wash equipment will be established when moving into the works phase that will require these controls; and
- all site personnel will enter and leave the site via a decontamination unit. Personnel will be required to wash and clean dirty boots before leaving the exclusion zone.

5.3.3 Isolation and Capping

The main objective of the selected soil remediation option (Isolation and Capping) is to restrict access to contaminated soil and to minimise potential health risks. The isolation and capping soil remediation option will be undertaken in conjunction with the proposed landscape plan (refer to Figure 3).

It is noted that in some areas the implementation of a minimum of 0.5m capping will be difficult and impractical and therefore a summary of hierarchy of mitigation measures is presented on Table 11.

The following requirements should be considered during the actual remediation process:

- soil validation requirement - Section 5.4;
- quality assurance and quality control – Section 5.5; and
- materials handling and management – Section 5.6.

TABLE 11 PROPOSED REMEDIATION/MITIGATION MEASURES

No.	Task	Proposed Hierarchy of Remediation / Mitigation Measures
1	New Playgrounds, drinking fountains and dog facilities	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a min of 0.5m and replace with 0.5m of clean fill material and should be underlain by a warning liner; or • Excavate excess soil (if necessary) and if any of the mitigation measures cannot be applied, excavation will have to be validated (refer to Section 5.4.4); or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access; or • Install a pavement, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.
2	Existing buildings	• These areas are covered with concrete and/or other non-permeable flooring and therefore there will be no direct contact with the contaminated soil, no additional mitigation measure is recommended.
3	Existing mounding	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a min of 0.5m and replace with 0.5m of clean fill material and should be underlain by a warning liner. The excess soil can be moved to the additional mounding; or • Excavate excess soil (if necessary) and if any of the mitigation measures cannot be applied, excavation will have to be validated (refer to Section 5.4.4); or • Install a geotextile lining (permeable fabrics, typically made from polypropylene or polyester) followed by a minimum of 0.3m capping;
4	Additional mounding	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Install a geotextile lining (permeable fabrics, typically made from polypropylene or polyester) followed by a minimum of 0.3m capping; or • If higher than 0.5m, impacted soil from other areas can be used followed by 0.5m clean fill capping.

No.	Task	Proposed Hierarchy of Remediation / Mitigation Measures
5	Retaining walls	Due to the stability and drop off issue from the wall to street level, a 0.5m capping is not advisable. Therefore, the following options are recommended: • Concreting of areas to avoid soil contact; or • Divert the pathways away from the walls to restrict access; or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.
6	Existing blue stone and brick pavement	• As these areas are being used for walkways/pathways only and direct contact is not expected, no mitigation measure is recommended.
7	Landscape areas including bushlands and garden beds	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a minimum of 0.5m and replace with clean fill material and should be underlain by a warning liner; or • Excavate excess soil (if necessary) and if any of the mitigation measures cannot be applied, excavation will have to be validated (refer to Section 5.4.4); or • Install a geotextile lining (permeable fabrics, typically made from polypropylene or polyester) followed by a minimum of 0.2m capping and/or compacted gravel toppings and then followed by a minimum of 0.1m mulch (limited to localised area only); or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.
8	Existing and new pathways	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a min of 0.5m and replace with 0.5m of clean fill material and should be underlain by a warning liner; or • Excavate excess soil (if necessary) and if any of the mitigation measures cannot be applied, excavation will have to be validated (refer to Section 5.4.4); or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access; or • Install a pavement, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.
9	Installation of new benches, BBQ, tables, signage, rubbish bins, rotunda, Lighting and electricity infrastructure, drainage and weekend farmer's market area	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a min of 0.5m and replace with 0.5mclean fill material and should be underlain by a warning liner; or • Excavate excess soil (if necessary) and if any of the mitigation measures cannot be applied, excavation will have to be validated (refer to Section 5.4.4); or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access; or • Install a pavement, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.

No.	Task	Proposed Hierarchy of Remediation / Mitigation Measures
10	Removal of trees	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a min of 0.5m and replace with 0.5mclean fill material and should be underlain by a warning liner; or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.
11	Retention of trees	A tree protection zone is required, depending on the size of the tree any future excavation will need to be limited outside the tree protection zone. To avoid soil contact to cover off the required tree protection zone, the following options are recommended: • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access; or • Install a pavement, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.
12	Public Art, outside theatre area	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a minimum of 0.5m and replace with 0.5mclean fill material and should be underlain by a warning liner; or • Install a decking, liner and 0.2m capping and/or compacted gravel toppings to avoid soil access; or Install a pavement, liner and 0.2m capping and/or compacted gravel toppings to avoid soil access; or • Extend the infrastructure on a paved/concreted area.
13	Wetlands	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a minimum of 0.5m and replace with clean fill material and should be underlain by a warning liner; or • Install a geotextile lining (permeable fabrics, typically made from polypropylene or polyester) followed by a minimum of 0.3m capping.
14	Other areas (shelter, structures or other items not identified in the landscape plan to be installed in the future).	• Capping of a minimum of 0.5m and should be underlain by a warning liner; or • Excavate a min of 0.5m and replace with clean fill material underlain by a warning line; or • Install a decking, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access; or • Install a pavement, 0.2m capping and/or compacted gravel toppings and liner to avoid soil access.

The decision of which mitigation measures to be implemented will be finalised upon completion of the pre-start survey. Following the pre-start survey, a detailed plan will be prepared and a formal endorsement will be sought from the appointed auditor.

The summary of the general equipment that is anticipated to be used to excavate, transport and stockpile excavated material is provided below:

- *20 tonne excavator* – whenever possible, an excavator in the range of 20 tonne rating would be used to undertake the excavation works and backfilling. The size of the excavator will allow for the selective excavation of impacted material, as well as facilitating easy loading of trucks;

- *haul trucks* – one to two on-site haul trucks with a capacity of 10 to 20 m^3 will be used on site to transfer excavated material to another site; and
- *front-end loader/Backhoe* – a front-end loader and/or backhoe may be used to assist in material loading.

5.3.4 Additional soil investigation

During the actual capping and isolation works, if none of the proposed mitigation measures can be applied (e.g structural integrity issue or significant amount of vegetation or trees with high retention values) then those areas will have to be further assessed with a combination of targeted and grid sampling to check if the existing ground surface may remain without an unacceptable risk to both human health and environment.

If additional soil investigation is required, a work plan will have to be prepared and submitted to the appointed auditor for endorsement.

5.3.5 Soil Remediation Report

Upon completion of the remediation works including the additional soil investigations (if found to be necessary), a remediation report will be prepared and will include the following details:

- a summary of the methodologies and/or remediation processes applied to all field works;
- comparison of reported soil chemical concentrations taken as part of the validation process and/or soil samples taken from the additional soil investigation (refer to Section 5.3.4, if required) with relevant screening level criteria to assess the risks posed by contamination at the site to the proposed land use, other receptors, and the surrounding environment;
- inclusion of relevant records such as procedures and tracking of all materials transported within, to and from the site, photographic, video, database, survey, electronic reports and other written records; and
- preparation of figures but not limited to site location map, site layout plan, soil results and mitigation measures mapping.

5.3.6 Groundwater Management

Environmental Earth Sciences considers that the risk posed by the current groundwater status is low and the implementation of active or *in-situ* remediation of groundwater at the site is considered to be impracticable based on the following reasons:

- given the fact that the groundwater discharging from the site is captured via the surrounding sewer network (acting as a physical barrier) including to the east of the site after flowing underneath the residential properties;
- low likelihood of use of the groundwater for any beneficial uses due to the availability of reticulated mains water; and
- low yield of the Brighton group aquifer.

Despite the low likelihood of use of the groundwater for the relevant extractive beneficial uses (potable water, stock watering, agricultural parks and garden, industrial water use, primary contact recreation) in the residential area to the north east of the site, this potential beneficial use cannot be discounted in this area and therefore implementing a Groundwater Quality Management Plan (GQMP) is recommended.

Based on our assessment detailed above, the practical way of managing the groundwater impacts is not to undertake any active or passive groundwater remediation other than the

implementation of regular groundwater monitoring as an essential component of do nothing or monitored natural attenuation option.

After the soil remedial program, a groundwater monitoring program will be established to check the trends of CoC concentrations and to check if the current groundwater status will either remain stable or decrease following the soil capping and isolation of impacted soil on-site.

The monitoring program will be developed based on requirements of SEPP (GoV) and EPA Publication 669 – *Groundwater Sampling Guidelines*.

Groundwater samples will be collected from selected groundwater wells that will be further discussed in the GQMP document. The wells identified have been selected based upon previous recorded concentrations and the locations of the wells relative to the source, the site boundary, and residential properties.

The proposed scope of work for the monitoring program is detailed below:

- preparation of job hazard analysis and other relevant occupational health and safety documents;
- gauging of selected groundwater monitoring wells located on and off-site with an oil / water interface meter to measure standing water levels (SWL) and the thickness of light or dense NAPL should they be present;
- if the interface meter indicates LNAPL is present, it will be confirmed through the use of a clear disposable bailer;
- purging and sampling of groundwater from within the groundwater monitoring wells using low flow techniques (micropurge);
- field water quality parameters will be measured (including pH, electrical conductivity, dissolved oxygen, oxidation reduction potential and temperature) during purging until the parameters have stabilised in accordance with EPA Publication 669;
- collection and analysis of groundwater duplicate, triplicate, rinsate and trip blank samples for quality assurance/quality control (QA/QC) purposes.
- groundwater samples will be field filtered prior to collection into laboratory supplied, acid preserved, sample bottles for heavy metals analysis;
- analysis of groundwater samples for one or more of the analytical schedule:
  - ionic balance including pH, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-} and F^{-};
  - heavy metal (Al, As, Cd, Cu, Fe, Pb, Ni, Zn, Co, Se, Bo and Mn);
  - TPHs (including silica gel clean-up);
  - MAHs (including trymethylbenzene and benzene, toluene, ethylbenzene and xylenes);
  - Naphthalene; and
  - total cyanide;
- all samples will be immediately chilled and stored on ice (<4^{o}C) prior to and during transit to the laboratory;
- water from groundwater well development and purging activities will be collected for appropriate off-site disposal;

- groundwater sampling equipment will be cleaned between each sampling event. Specifically, all groundwater sampling equipment will be cleaned in a Decon 90 solution and rinsed in a separate vessel of deionised water. New disposable gloves will be worn during each sampling and replaced after each sample is collected; and
- preparation of groundwater sampling report which will include summary spreadsheets of the monitoring data, a comparison of contaminant levels with the adopted groundwater quality objectives, and recommendations for future monitoring.

5.4 Remediation Validation Requirement

5.4.1 Imported fill Validation

Significant amounts of imported clean fill material will be required as part of the remediation works. Validation of imported fill will involve undertaking an assessment of the source of the fill material and the collection of representative validation samples and should be collected in accordance with EPA Publication Industrial Waste Resource Guideline (IWRG) 702. The objective of the sampling program will be to confirm that the material is below the NEPM 2013 criteria for recreation and open space use across the SMG except in the Southport Community Nursing Home which will be compared to residential land use.

The frequency of sampling will be dependent on the source of the fill material. If the material is brought onto the site from a quarry, and the material is homogeneous, validation will consist of:

- a certificate demonstrating the physical and chemical quality of the fill, including supporting test data; and
- confirmation samples collected at a frequency of 1 sample per 250 m^3.

If the imported material cannot be certified as clean quarry material, a Phase 1 Environmental Site Assessment (ESA) may be required or the proposed source of the material will be inspected and the frequency of testing dependant on the results of the inspection. In addition, approval or consultation should be sought to the appointed auditor prior to importation.

If the Phase 1 ESA or inspection indicates that the source location has no prior uses that could adversely impact soil quality, samples will be collected at one composite sample per 100 m^3.

If the inspection indicates that the source location could have some prior uses that adversely impacted soil quality, then it will not be considered for site use.
Whenever possible, samples will be collected from the source location, prior to import of the material to the site.

Table 12 below presents the typical laboratory testing program for imported fill material.

TABLE 12 PROPOSED IMPORTED CLEAN FILL VALIDATION ANALYTES

No.	Sample Type	Typical Analytes
1	Imported Clean Fill Validation	• IWRG 621 Screen (approximately 25% of all the soil samples collected) • Heavy Metals (As, Cd, Cr, Cu, Ni, Pb, Zn and Hg); • Polycyclic Aromatic Hydrocarbons (PAH) and Phenols; • Total Petroleum Hydrocarbons (TPH); • Volatile organic compounds (VOCs); • Organo chlorine (OC) Pesticides; and • Polychlorinated byphenyl (PCB).

5.4.2 Capping thickness and/or other mitigation measures

An Initial and final site survey will have to be undertaken to validate the thickness of the capping placed. In addition, the qualified site environmental scientist or engineer will have to measure the imported fill being place to ensure that capping will be a minimum of 0.5m or if other appropriate isolation measure has been undertaken.

Comprehensive records of all activities undertaken at the site, procedures and tracking of all materials transported within, to and from the site (refer to Section 5.6 for further detail) will be maintained as part of the remediation program to demonstrate that appropriate soil tracking processes have been employed and the correct mitigation measures have been implemented.

Record documentation media will include but not limited to photographic, video, database, survey, electronic reports and written records.

5.4.3 Site Characterisation Soil Sampling

If additional investigation (refer to Sections 5.3.4 and 5.3.5) is required in areas where any of the mitigation measures cannot be undertaken then the proposed analytes is detailed on Table 13. In addition, aesthetics should also be considered such presence of general gasworks waste, tar and asbestos as part of the additional site characterisation.

TABLE 13 SOIL CHARACTERICATION SAMPLING

Sample Type	Analytes	Comments
Soil samples collected during site characterisation. **At least two samples per investigation location will be collected.**	Heavy Metals (As, Cd, Cr, Cu, Ni, Pb, Zn and Hg)	All samples analysed
	PAH and Phenols	All samples analysed
	MAH's	All samples analysed
	TPH	All samples analysed
	Cyanide, Sulfate and sulfides	25% of samples selected for analysis

5.4.4 Validation of Excavations

Validation of excavations is not considered necessary if the 0.5m capping or imported fill or other mitigation measures can be applied. However, if capping or other proposed mitigation measures cannot be applied after excavations (eg. removal of excess soil, cutting of existing mounding, etc) then the sampling of the excavation base and side walls will be required to characterise the level of contamination and further excavation may be required until all the soil results were reported to be below the adopted soil criteria and no visible sign of general gasworks waste.

Excavation base and sidewall samples will be collected at a frequency of one sample per 5m intervals (taken from mid-point of side wall, or at 1.5 m depth intervals in excavations greater than 1.0m depth) along the linear length of the excavation.

Excavation base samples will consist of discrete samples collected to depths of 100 mm and 500 mm at each location. Sidewall samples will generally consist of a scrape along the wall over a typical depths of 100 and 500 mm. Samples will be selected so as to be representative of each stratum exposed in the sidewall or base of the excavation.

All samples will be tested for the list of analytes on Table 14.

TABLE 14 EXCAVATION VALIDATION SAMPLING

Sample Type	Analytes	Comments
Soil samples collected during site characterisation. **At least two samples per investigation location will be collected.**	Heavy Metals (As, Cd, Cr, Cu, Ni, Pb, Zn and Hg)	All samples analysed
	PAH and Phenols	All samples analysed
	MAH's	All samples analysed
	TPH	All samples analysed
	Cyanide, Sulfate and sulfides	25% of samples selected for analysis

5.4.5 Stockpile Validation

Validation of the stockpiled material from on-site excavations is not considered necessary if the stockpiled material will be used on-site and covered with any of proposed mitigation measures to avoid direct contact with future users. However, if CoPP opted to dispose the soil off-site the stockpiled material will then be sampled in accordance with IWRG 621.

5.5 Quality Assurance/Quality Control

A project specific quality system developed in accordance with industry accepted standards will be developed and adopted for the duration of the project. Relevant industry accepted standards include the NEPM guidelines and AS4482-1 2005. All contractors and subcontractors will use this system to ensure that the remediation works are carried out effectively. As part of this system, a regular internal audit will be undertaken to ensure that all components of the quality system are followed.

The Quality Plan will include:

- project organisation and responsibility;
- survey control;
- data review and data validation;
- soil tracking procedures;
- material handling and management procedures;
- soil sample collection and handling procedures;
- quality control measures to be implemented for sampling;
- decontamination measures;
- field testing measures and equipment calibration;
- water sample collection and handling;
- progressive reporting requirements;
- documentation of field activities and sample tracking (e.g. chain of custody and labelling);
- laboratory sample analysis program;
- field QA/QC program;
- provision for monthly QA/QC reporting; and
- reporting of non-conformances and rectification measures.

5.5.1 Laboratory QA/QC

All laboratory analyses will be carried out by a NATA registered laboratory for the nominated tests. Appropriate detection limits will be used for the level of reporting required, where practicable. An outline of the nominated laboratory soil and groundwater QA/QC program is outlined below. Note that the extent of internal laboratory QA/QC varies between laboratories.

Progressive QA/QC results will be reported to check the quality of potential sampling proposed in Sections 5.4.3, 5.4.4 and 5.4.5. This approach will ensure that the data integrity is maintained throughout the course of the project.

Inorganic Quality Assurance

Internal laboratory QA/QC procedures for inorganics include:

- 1 x Method Blank per analytical lot of samples;
- 1 x Standard Reference Material (laboratory Control Standard) per lot of samples;
- 2 x Matrix Spikes per analytical lot of samples; and
- 2 x Laboratory Duplicates per analytical lot of samples.

An analytical lot is defined as 20 samples of similar matrix processed for analysis as one unit.

5.5.2 Organic Quality Assurance

Internal laboratory QA/QC procedures for organics include:

- 1 x Method Blank per analytical lot of samples;
- 1 x Single Control Sample (SCS) containing all target compounds per analytical lot of samples;
- 1 x Duplicate Control Samples (DCS) containing all targets compounds per analytical lot of samples;
- Appropriate USEPA Surrogate compounds (or equivalent) added and reported for all samples;
- 1 x Matrix Spike containing USEPA representative target compounds per analytical lot of samples;
- 1 x Matrix Spike Duplicate containing USEPA representative target compounds per analytical lot of samples; and
- 1 x laboratory Duplicate per 10 sample lot.

An analytical lot is defined as 20 samples of similar matrix processed for analysis as one unit.

5.5.3 Field Duplicates

Field duplicates will be collected as part of the field sampling procedures. This includes samples collected for all validation programs.

Relative percent differences between the original and field duplicate samples will be reviewed as part of the field QA/QC program.

Inter-Laboratory Duplicates
Inter-laboratory duplicates will be collected and dispatched as part of the site validation process. Split samples (inter-laboratory duplicates) will be collected on the basis of one sample for every 20 samples analysed.

Intra-Laboratory Duplicates
Intra-laboratory duplicates will be collected and dispatched on the basis of one sample for every 20 samples analysed.

Rinsate Blanks
One rinsate blank will be collected each day of sampling, where appropriate.

Trip Blanks
One trip blank will be collected and analysed for each esky or sampling round, whichever is greater.

5.6 Materials Handling and Management

5.6.1 Materials Tracking

All materials handled during remediation will be tracked in order to allow verification of the correct movement and handling of the materials. The system will track materials and will provide detailed information on the location and quantity of all material movements both on and off site (if required), so that the material being handled can be identified and accounted

for. The tracking system shall include accurate tracking of stockpiles or imported fill material throughout the entire material handling stage. This will lead to a reduction in the risk of cross-contamination between stockpiles or imported fill material, as well as minimising the volumes of material requiring containment.

A register of all analytical results for stockpiles, imported fill material and excavations will be kept on-site. Copies of the results and a sample location plan will be available to be viewed by the inspecting authority/ person.

Standard forms shall be prepared as part of the Materials Tracking Procedure. The forms and their function shall include, but not be limited to:

- *Material Excavation Form* - Providing a record of excavated materials for each excavation on the site including the date, material type, excavated quantity, origin and intended destination;
- *Material Stockpiling Form* - Provides a record of all materials placed in each of the site stockpiles. The form will include the date, material type, stockpiled quantity, origin and intended end use;
- *Material Placement Form* – This form provides a record of all materials backfilled on the site and includes the date, material type, quantity backfilled and origin;
- *Off-site Transport Form* - Providing a record of materials removed from the site and including the material type, quantity, origin, and shipping destination; and
- *Imported Fill Form* - Providing a record of materials imported to the site including the date, material type, quantity, point of origin, intended use and the suitability of the material for use as backfill at the site.

During the works, each form shall be completed on a daily basis and collated into a cumulative log for each process on a weekly basis.

6 REMEDIATION GOALS

6.1 Adopted Remediation Criteria

6.1.1 Criteria for proposed soil remediation option

The main objective of the selected remediation option is to restrict access to contaminated soil to minimise potential health risk. In order to achieve this objective, a minimum of 0.5 m capping to the existing ground surface or comply with the proposed hierarchy of mitigation measures discussed on Section 5.3.3 will be used as a remediation criteria.

The fill material that will be used for capping and the additional soil investigation (if required) must firstly meet the requirements specified in EPA Publication IWRG621 Soil Hazard Characterisation and Management for fill and have suitable soil properties to facilitate growth of vegetation and then will be assessed against the soil quality objectives below.

The following details the regulatory framework and basis for selection of soil and groundwater quality objectives.

6.1.2 Soil quality objectives

Environmental Earth Sciences refers to the NEPC (2013), *National Environment Protection (Assessment of Site Contamination) Amended Measure 2013* (here onwards referred to as the NEPM 2013) for environmental and health based investigation threshold levels for contaminant concentrations in soil.

6.1.3 Likely land use

Given the current zoning of the site and proposed used of the site, Environmental Earth Sciences proposes the site to be assessed against the objectives associated with:

- parks, recreational open spaces and playing fields for the gasworks park, and
- standard residential with garden/accessible soils for South Port Nursing Home.

6.1.4 Beneficial uses to be protected – land

The beneficial uses to be protected for parks and reserves with limited structures land use in accordance with the State Environment Protection Policy, *Prevention and Management of Contamination of Land* (Land SEPP 2002) are as follows:

- modified ecosystems;
- human health;
- buildings and structures;
- aesthetics; and
- production of food and flora and fibre.

The associated soil quality objectives for each of these protected beneficial uses are discussed in the following sections.

Modified ecosystems

The ecological investigation levels (EILs) assigned by the NEPM (2013) *Schedule B5a - Guideline on Ecological Risk Assessment* presents the methodology for deriving terrestrial EILs using both fresh and aged (i.e. > 2 years old) contamination for soil with the following land use types:

- areas of ecological significance;
- urban residential/public open space; and
- commercial / industrial.

The methodology that has been developed is to protect soil processes, soil biota (flora and fauna) and terrestrial invertebrates and vertebrates. The land use type closest to that of the site is urban residential / public open space (80% level of protection) and hence these EILs (refer to Table 15) have been adopted for his assessment as a preliminary screening. As the selected remediation option is to cap the entire the site, and there are no appropriate background concentrations available due to heterogeneity of the site, the proposed method to determine the ambient background concentrations will be based on Olszowy et al (1995). Refer to Table 15 for the proposed EILs.

TABLE 15 ENVIRONMENTAL INVESTIGATION LEVELS FOR SOIL

Chemical	Environmental investigation levels (mg/kg)
	NEPM 2013 Residential / Public Open Space
Metals and Inorganics	
Arsenic (As)	100[2]
Chromium (III)	410[6]
Copper (Cu)	200[3]
Lead (Pb)	1,135[4]
Nickel (Ni)	275[5]
Zinc (Zn)	440[1]
Polycyclic Aromatic Hydrocarbons (PAHs) AND PESTICIDES	
Naphthalene	170[8]
DDT	180[7]

Notes:

1. Zn – using Table 1B(1) – soil specific added contaminant limits for aged Zn in soil using pH 6.0, CEC 20% and Table 14 for the added background concentration, old suburb and low traffic.
2. As based on lowest observed effect and 30% effect concentration data Naphthalene – using Table 40, based on lowest observed effect and 30% effect concentration data
3. Cu – using Table 58, old suburb with low traffic and Table 1B(2) – soil specific added contaminants limit for aged Cu using a pH of 6.
4. Lead – using Table 67, old suburb with low traffic and Table 68 based on lowest observed effect and 30% effect concentration data.
5. Nickel– using Table 80, old suburb with low traffic and Table 81 based on lowest observed effect and 30% effect concentration data using a conservative Cation Exchange Capacity of 20%.
6. Cr (III)– using Table 80, old suburb with low traffic and Table 1(B)3 soil site specific added contaminants limit for aged Cr(III).
7. DDT – using Table 43 of Schedule B5.
8. Naphthalene - based on Table 40 freshly contaminated soil based on lowest observed effect concentration and 30% effect toxicity data.

Human health

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

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

Given that the site is currently being used as open space and nursing home, a combination of HIL A (Column 1 Southport Community Centre) and HIL C for the rest of the Site is recommended as the assessment criteria for comparison with actual soil conditions (refer to Table 16).

TABLE 16 HEALTH INVESTIGATION LEVELS FOR SOIL

Chemical	Health-based investigation levels (mg/kg)			
	HIL A	HIL B	HIL C	HIL D
Metals and Inorganics				
Arsenic[2]	100	500	300	3 000
Beryllium	60	90	90	500
Boron	4500	40 000	20 000	300 000
Cadmium	20	150	90	900
Chromium (VI)	100	500	300	3600
Cobalt	100	600	300	4000
Copper	6000	30 000	17 000	240 000
Lead[3]	300	1200	600	1 500
Manganese	3800	14 000	19 000	60 000
Mercury (inorganic)[5]	40	120	80	730
Methyl mercury[4]	10	30	13	180
Nickel	400	1200	1200	6 000
Selenium	200	1400	700	10 000
Zinc	7400	60 000	30 000	400 000
Cyanide (free)	250	300	240	1 500
Polycyclic Aromatic Hydrocarbons (PAHs)				
Carcinogenic PAHs (as BaP TEQ)[6]	3	4	3	40
Total PAHs[7]	300	400	300	4000
Phenols				
Phenol	3000	45 000	40 000	240 000
Pentachlorophenol	100	130	120	660
Cresols	400	4 700	4 000	25 000
Organochlorine Pesticides				
DDT+DDE+DDD	240	600	400	3600
Aldrin and dieldrin	6	10	10	45
Chlordane	50	90	70	530
Endosulfan	270	400	340	2000

Chemical	Health-based investigation levels (mg/kg)			
	HIL A	HIL B	HIL C	HIL D
Heptachlor	6	10	10	50
HCB	10	15	10	80
Methoxychlor	300	500	400	2500
Mirex	10	20	20	100
Toxaphene	20	30	30	160
Other Organics				
PCBs[8]	1	1	1	7

Notes:

1. Investigation levels from Table 1A(1) of Schedule B1 Guideline on investigation levels for soil and groundwater levels.
2. Generic land uses are described in detail in Schedule B7 Section 3 of the NEPM 2013
3. HIL A - Residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake (no poultry), also includes childcare centres, preschools and primary schools.
4. HIL B - Residential with minimal opportunities for soil access; includes dwellings with fully and permanently paved yard space such as high-rise buildings and apartments.
5. HIL C - Public open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and footpaths. This does not include undeveloped public open space where the potential for exposure is lower and where a site-specific assessment may be more appropriate.
6. HIL D - Commercial/industrial, includes premises such as shops, offices, factories and industrial sites.
7. Arsenic: HIL assumes 70% oral bioavailability. Site-specific bioavailability may be important and should be considered where appropriate (refer Schedule B7).
8. Lead: HIL is based on blood lead models (IEUBK for HILs A, B and C and adult lead model for HIL D where 50% oral bioavailability has been considered. Site-specific bioavailability may be important and should be considered where appropriate.
9. Methyl mercury: assessment of methyl mercury should only occur where there is evidence of its potential source. It may be associated with inorganic mercury and anaerobic microorganism activity in aquatic environments. In addition the reliability and quality of sampling/analysis should be considered.
10. Elemental mercury: HIL does not address elemental mercury. A site-specific assessment should be considered if elemental mercury is present, or suspected to be present,
11. Carcinogenic PAHs: HIL is based on the 8 carcinogenic PAHs and their TEFs (potency relative to B(a)P) adopted by CCME 2008 (refer Schedule B7). The B(a)P TEQ is calculated by multiplying the concentration of each carcinogenic PAH in the sample by its B(a)P TEF, given below, and summing these products.

PAH species	TEF	PAH species	TEF
Benzo(a)anthracene	0.1	Benzo(g,h,i)perylene	0.01
Benzo(a)pyrene	1	Chrysene	0.01
Benzo(b+j)fluoranthene	0.1	Dibenz(a,h)anthracene	1
Benzo(k)fluoranthene	0.1	Indeno(1,2,3-c,d)pyrene	0.1

Notes:

1. Total PAHs: HIL is based on the sum of the 16 PAHs most commonly reported for contaminated sites (WHO 1998). The application of the total PAH HIL should consider the presence of carcinogenic PAHs and naphthalene (the most volatile PAH). Carcinogenic PAHs reported in the total PAHs should meet the B(a)P TEQ HIL. Naphthalene reported in the total PAHs should meet the relevant HSL.
2. PCBs: HIL relates to non-dioxin-like PCBs only. Where a PCB source is known, or suspected, to be present at a site, a site-specific assessment of exposure to all PCBs (including dioxin-like PCBs) should be undertaken.

In addition, management limits for TPH fractions F1-F4 in soil under residential/parkland and public open space will also be considered (refer to Table 17).

TABLE 17 MANAGEMENT LIMITS FOR TPH FRACTIONS F1–F4 IN SOIL

TPH fraction	Soil texture	Management Limits[1] (mg/kg dry soil)
		Residential, parkland and public open space
F1[2] C_6- C_{10}	*Coarse*	700
	Fine	800
F2[2] $>C_{10}$-C_{16}	*Coarse*	1000
	Fine	1000
F3 $>C_{16}$-C_{34}	*Coarse*	2500
	Fine	3500
F4 $>C_{34}$-C_{40}	*Coarse*	10 000
	Fine	10 000

Notes:

1. Management limits are applied after consideration of relevant ESLs and HSLs
2. Separate management limits for BTEX and naphthalene are not available hence these should not be subtracted from the relevant fractions to obtain F1 and F2.
3. Management limits from Table 1 B(7) of Schedule B1 Guideline on investigation levels for soil and groundwater levels.

Aesthetics

The Land SEPP states that "Contamination must not cause the land to be offensive to the senses of human beings".

Buildings and structures

The Land SEPP states, *"Contamination must not cause the land to be corrosive to or adversely affect the integrity of structures or building materials"*. The potential for the condition of soils at the site to adversely impact upon buildings (AS2159-2009 Piling, Design and Installation and AS3600-2009 Concrete Structures) includes:

- elevated sulfate concentrations or acidic (low pH) soil conditions which are detrimental to some concrete structures; and
- ingress of contaminants into subterranean service lines (such as ingress into water supply pipelines).

Production of food and flora and fibre

The Land SEPP states that "*Contamination of land must not:*

- adversely affect produce quality or yield; and
- affect the level of any indicator in food, flora and fibre produced at the site (or that may be produced) such that the level of that indicator is greater than that specified by the Australian New Zealand Food Authority, Food Standards Code."

There are no specific soil quality objectives provided for this beneficial use within the Land SEPP. Therefore an evaluation of this beneficial use has been undertaken with comparison to maintenance of ecosystems beneficial use guidelines and also it is unlikely that a fruit bearing tree or vegetable will be grown on-site. However, it should be noted soils to be imported onsite as part of the capping should have suitable properties to facilitate growth of vegetation (e.g. soil structure, nutrient levels, etc).

7 SITE MANAGEMENT ACTIVITIES

The details provided in this (and subsequent) sections are not intended to be a definitive list of the requirements for occupational health and safety or protection of the environment during remedial works. Details within this RAP are provided for guidance purposes only. The contractor undertaking the works should satisfy themselves that their operational procedures meet current legislation for their intended works.

More detailed approach to site, community, environment, contractor and OH&S management during remediation is contained within the updated CMP's. This RAP is to be used in conjunction with the CMP's. A summary of relevant procedures for undertaking remedial works is provided below.

7.1 Community liaison

It is recommended that a community liaison program be managed by Council prior to works commencing informing them of at least the proposed works, timing, human health and environmental protection measures. The program should include a 24-hour telephone number for complaints, a letter drop and a community meeting prior to works and a separate emergency services briefing as a minimum.

Local residents, including neighbouring commercial properties and residential dwellings in the immediate area, should be notified prior to work commencing.

Protocols should be established detailing management of the complaints. The CMP's provides more detail in relating to the handling of complaints, including:

- notification of how to make a complaint;
- complaint handling; and
- recording of complaints and register.

It is noted that CoPP have already commenced a community consultation/engagement program in order develop the proposed landscape plan.

7.2 Service locations

Before the commencement of excavation or relocation activities, all services on-site such as lighting power, water, stormwater, sprinkler system, gas and telecommunications cables should be located and disconnected where necessary. All persons working on-site should be made aware of the location of services.

7.3 Site preparation, notifications and licenses

All permits and development approvals pertaining to any part of the isolation or capping works will be applied for and received before proceeding with that relevant phase of work.

Prior to works commencing any existing fencing should be checked and additional fencing added when required to make the site secure. Warning signs will be erected, including; "hard hat area only", "visitors must report to the site manager" and "keep out". Any run-off control measures will be installed and the routes for trucks in and out of the site clearly marked. Temporary accommodation including an office area lunch room and toilets should be supplied if not present on-site.

7.4 Access and decontamination procedures

Access to the site will be limited. The site will be fenced which will further limit access by members of the public who may injure themselves or vandalise the safety works.
During excavation, relocation and backfilling of soil, safety barricades will be erected around open pits/trenches to prevent persons and machinery falling into them if the works are 1.0 m depth or left open unsupervised.

As trucks or other machineries may come into contact with exposed soil their wheels and undercarriage may require brushing or washing down each time they leave the site to prevent any material being tracked offsite. Rumble bars and a wash down area may be required.
Clean fill material will be stockpiled on a designated area with lining and appropriate bunding (e.g. hay bales) so that it does not come into contact with potentially contaminated soil.

7.5 Weather

The site should not be worked during moderate to heavy rainfall periods; this will minimise erosion, surface run-off and other form of contaminants transfer and potential occupational health and safety risks.

7.6 Ancillary works

Before final demobilisation from the site, all rubbish and surplus materials used for the purpose of demolition of fixtures, temporary fencing and shoring should be removed. Any fencing that existed prior to the arrival of the contractor/consultant on site may be left as is, unless otherwise requested by the client.

8 ENVIRONMENTAL MANAGEMENT

The environment on-site, adjoining properties and the surrounding area shall at all times be protected from impacts derived from activities during remedial works. Potential environmental impacts associated with the site will be controlled.

The approach for protection of the environment after the remedial works should be detailed in the updated Construction Management Plan (CMP) including but not limited to methods to install and operate all environmental control measures according to current and relevant

Australian Standards (AS), federal and state guidance and approved industry codes of practice.

A summary of the potential environmental issues is detailed below.

8.1 Odour management

Odorous material will be excavated during the upgrade of the existing mounding, installation of additional underground infrastructure and potential future maintenance requirements. The works will be undertaken to minimise odour generation and odours leaving the site. The following measures may be implemented as appropriate:

- the area of exposed impacted soil will be minimised as much as possible;
- odorous stockpiles will be covered by tarpaulins, covered with a layer of non-odorous material or sprayed with an odour suppressing spray or sealant;
- odour suppression sprays and foams will be utilised over excavations and stockpiles, and elsewhere on the site where odours are persistent;
- excavation faces that expose contaminated material will be covered with plastic sheeting, geofabric or odour suppressant foam;
- reducing the rate of work;
- ceasing work if wind direction is likely to blow odours towards residential neighbours; and
- all loads of material leaving the site (if required) will be securely covered.

Regular odour surveillance walks will be undertaken along the boundaries will be undertaken (minimum of once daily) with the observations recorded in the Daily Site Diary. Field staff may also use a portable photo-ionisation detector (PID) and landfill gas analyser during odour surveillance walks. Upon detection, staff will investigate the source of the odours and may upgrade odour suppression systems until odours are no longer at unacceptable levels at the site boundary.

8.2 Dust management

During the proposed remediation works, dust emission will be an issue and therefore it needs to be managed using some of the following:

- hessian will be located along any section of the site fence located in the vicinity of remediation areas;
- hessian covered screens may be used in open areas to minimise dust;
- regular dampening or cleaning of roads and pavements using a water cart;
- protecting stockpiled materials by sealing (compacting) with an excavator bucket, tarpaulins, consolidation, erection of hessian wind brakes, and/or dampening down the surface of stockpiled soil;
- ceasing work in strong winds;
- regular checking of dust emissions using the digital real-time read-out equipment (e.g. DustTrak) downwind of the excavation works;

- undertaking the loading or unloading of dry soil as close as possible to the stockpiles or skip bins to prevent the spread of loose material around the site; and
- reducing the expanse of cleared land to the minimum required to achieve a safe and economical working environment.

Dust is may also be produced during the transfer of materials to and from the site. The Contractor will be responsible for minimising dust generation for vehicles leaving the site and during transportation.

8.3 Vapour management

Vapour (from soil and groundwater potentially impacted with hydrocarbons) may occur during remediation. During the proposed works, a qualified consultant should always be on-site to monitor the presence/absence of volatile organic compounds using either a PID or a four gas metre. To measure the risk to potential site workers soil vapour badges will be worn at times when vapours may be produced or at times samples should be tested at NATA accredited laboratories.

In addition to this, any potential off-gases from the remediation may also be treated via granulated activated carbon (GAC) drums and/or air scrubbers.

8.4 Waste management

The approach will be to apply the principles (in order of preference) of reduce, reuse, recycle for waste generation from construction activities. This section on waste management does not include potentially contaminated soil which is covered above.

The waste control techniques include:

- assessing the types and volumes of wastes that are likely to be produced;
- evaluating waste minimisation opportunities based on technical, economic and environmental criteria;
- preparing and implementing waste management practices; and
- reviewing waste management program periodically to assess adherence and to facilitate continual improvement.

8.5 Noise and vibration management

The target is to maintain remediation noise below the maximum levels specified in the *Noise Control Guidelines* and *OH&S (Noise) Regulations 2004* and to generally minimise the impact of construction generated noise and vibration upon the environment.

Excessive vibration issues are not expected for this project based on the works proposed. The control strategy is to use estimated noise and vibration impacts in the planning process as a criterion in selecting and refining construction methods. A noise and/or vibration monitoring program may be used to verify the effectiveness of the control techniques.

Noise producing machinery and equipment should only be operated between the hours of 7.00 am and 5.00 pm Monday to Friday, unless requested otherwise by Council. No work should be undertaken on public holidays and weekends. If it is necessary to work outside these hours, local residents should be notified.

Australian Standard AS2460 outlines guidelines for the minimisation of noise on construction and demolition sites and these should be adhered to at all times. Should, however, machinery which has a potential to generate prolonged noise be required, then the activity will be reduced to that which is completely necessary with appropriate planning to ensure tasks are completed as quickly as possible.

Excessive vibration issues are not expected for this project based on the works proposed. The control strategy is to use estimated noise and vibration impacts in the planning process as a criterion in selecting and refining construction methods. A noise and/or vibration monitoring program may be used to verify the effectiveness of the control techniques.

A noise incident occurs where:

1. a third party complains about noise emanating from the site to the EPA or the Works Manager;
2. the Works Manager suspects and can reasonably demonstrate by field observations, that noise levels from the site have exceeded guidelines; or
3. client suspect that noise levels from the site have exceeded guidelines.

Work will be immediately suspended on notification of the noise incident; the source of the noise will be identified. The activity will be assessed to determine if the work can be done with less noise or postpone work until a time that will cause less impact on neighbours.

8.6 Sediment and erosion control

The drains and where the temporary stockpiles will be placed during the excavation, relocation and backfilling works should be blocked or barricaded with the use of silt fencing, sandbags and/or hay bales to prevent offsite sediment movement.

8.7 Stormwater runoff

Any existing storm water inlets present on-site are to be blocked off using appropriate sediment controls, to prevent potentially impacted overland flows from entering the storm water system. For instance hay bale bunds down gradient of the exposed soil or a silt fence. All works where soil is exposed to potential storm water runoff must have erosion control measures implemented in accordance with Environment Protection Authority Publication 480 (1996) ─ *Environmental guidelines for major construction sites, best practice environmental management series.*

9 AIR QUALITY MONITORING

The purpose of the site air quality monitoring program is to demonstrate protection of community health and on-site workers throughout the capping and on-site transfer works. As such, the air quality program will be conducted primarily along the site boundaries during earthmoving activities to ensure that the stabilisation and containment activities do not adversely impact on the surrounding community.

9.1 Boundary – Air Quality Monitoring Program Summary

The major elements anticipated to be included in the boundary air quality monitoring program will include:

- collection of high volume air quality samples from one sampler at a downwind location along the site boundary with a particular focus on those site boundaries;
- collection of dust deposition samples at select boundary locations with a particular focus on those site boundaries adjacent to residential properties based upon weather conditions;
- collection of real time monitoring results using a Photo-ionisation Detector (PID) and DusTrak real time dust monitor as appropriate;
- qualitative odour assessment, description and measurement by appropriately trained personnel; and
- comparison of sample analysis results against trigger levels to assess whether site activities are impacting upon surrounding residents.

Air quality and dust monitoring equipment locations may vary subject to site activities and prevailing weather conditions.

9.2 Site Works Areas – Air Quality Monitoring Program Summary

The major elements to be included in the air quality monitoring program for specific works areas will include the collection of the following:

- real time monitoring results using a PID; and
- dust Trak real time dust monitor as appropriate.

9.3 Potential Off-site Receptors

Consideration of potential risks to off-site receptors (for example residents or off-site workers) must consider the exposure duration for receptors. On-site workers are typically exposed between 7:00 am and 5:00 pm (Monday to Friday) while off-site receptors may potentially be exposed for a 24 hour period every day. It is also important to consider any potential protection against possible exposure. For example, workers may have the appropriate personal protection equipment (PPE), while residents and passersby would not have the appropriate PPE.

In developing appropriate boundary trigger levels for the air quality monitoring program, factors including time spent outdoors and distance from the site must be considered for off-site receptors.

9.4 Remediation Air Quality Monitoring Trigger Levels

Table 18 below summarises the proposed air quality monitoring program for the site works at the site boundary. The trigger levels nominated below are based upon occupational health and safety criteria in the workplace and have been extrapolated to boundary conditions and off-site receptors using risk-based methodology.

TABLE 18 BOUNDARY AIR QUALITY MONITORING PROGRAM

Parameter	Location and Interval	Trigger Level (Meter Units/PPM-Above Background)	Response
Inhalable Dust **(total by real time sampling)**	Site perimeter shall be monitored continuously at two locations downwind of the excavation area during remediation works using DustTrak	<3[1] mg/m^3	Continue work and continue monitoring.
		≥3 mg/m^3 (sustained for more than 5 minutes) and <10[2]mg/m^3 (averaged over 8 hours)	Implement work face and stockpile dust mitigation measures. Continue monitoring.
Total Organic Vapours **(Total by PID)**	Initially four times daily during excavation of hydrocarbon or PAH impacted material. Subsequently at least twice daily in the breathing zone area at boundary. Additional monitoring may be carried out subject to prevailing weather and site conditions.	<5[3] ppm	Continue work and continue monitoring.
		≥5 ppm (Sustained for more than 5 minutes)	Review and amend work practices, Continue to monitor at hourly intervals to demonstrate compliance with trigger levels.
Odour **(Odour surveys and PID)**	Initially four times daily during excavation of hydrocarbon or PAH impacted material. Subsequently at least twice daily during other times. Odour surveys carried out regularly on-site. Additional monitoring may be carried out subject to prevailing weather and site conditions.	No odour.	Continue work and continue monitoring.
		Distinct odour present.	Instigate odour mitigation measures.
		Strong to very strong odour detected.	Cease work until new work practices established.

Notes:

1. Using a sensitive trigger level for coal dust (containing <5% quartz) based on Guidance on the interpretation of workplace exposure standards for airborne contaminants issued by SafeWork Australia
2. Based on standard nuisance dust exposure limit over an 8hr period based on Guidance on the interpretation of workplace exposure standards for airborne contaminants issued by SafeWork Australia
3. Based on national exposure standards for atmospheric contaminants in the occupational environment [NOHSC:1003(1995) – assuming that it's purely benzene

9.5 Remediation Off-Site/Boundary Dust Monitoring

Monitoring of boundary conditions will include consideration of community concerns. The sections above outline the air quality and odour emission controls and work practices required as part of the remediation works.

These plans, if necessary, will be reviewed and amended subject to monitoring results and unacceptable odour emissions.

10 OCCUPATIONAL HEALTH AND SAFETY

The general site safety is the responsibility of all personnel on-site. The requirements of this OH&S Management Plan must be followed at all times, and should be considered the minimum standards to be adopted during the works. Environmental Earth Sciences is responsible for providing a safe workplace environment on the site for the duration of the works. Any precautions or procedures not covered by this OH&S Management Plan shall not relieve the Contractor of any responsibilities or liabilities and they should develop additional procedures where appropriate.

A list of the key OH&S features to be considered is included below:

- contractor responsibilities;
- induction;
- competency and training;
- requirement for OH&S plan;
  - job safety analysis (JSA); and
  - safe method work statements (SWMS);
- site control;
- traffic management;
- site hazards:
  - physical hazards;
  - chemical hazards;
  - unknown or unexpected hazards;
- personal protective equipment (PPE);
- decontamination:
  - personnel; and
  - plant and equipment;
- site specific safety rules;
- safety inspection and audit schedule;
- first aid;
- accidents / incidents / near miss reporting;
- emergency response planning:

- o all emergencies;
- o spills or leaks;
- o fires / explosions;
- o plant / truck accident; and
- o damage to utilities

In addition to observation of site OH&S rules, the following is a list of relevant occupational health and safely documents that should be consulted in preparation for the work to be undertaken.

10.1 Relevant legislation and guidance documents

Legislation:

- Occupational Health and Safety Act 2004;
- Dangerous Goods Act 1985; and
- Environment Protection Act 1970.

Regulations:

- Occupational Health and Safety Regulation 2007;
- Dangerous Goods (Explosives) Regulation 2000; and
- Dangerous Goods (Storage and Handling) Regulation 2000.

Codes of Practice (WorkSafe VIC):

- WorkSafe Victoria (2005) — Industry Standard: Contamination Construction Sites;
- Confined Spaces (1997);
- Safety precautions in Trenching Operations (1988);
- Manual Handling (2000);
- Storage and Handling of Dangerous Goods (2000); and
- Occupational Health and Safety Induction Training for Construction (1999).

Standards (Australian Standards):

- AS4482.1 – Guide to the sampling and investigation of potentially contaminated soil. Part 1: Non-volatile and semi-volatile compounds;
- AS4482.2 – Guide to the sampling and investigation of potentially contaminated soil. Part 2: Volatile substances;
- AS4801 – Occupational health and safety management systems – Specification with guidance for use;
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ENVIRONMENTAL EARTH SCIENCES GENERAL LIMITATIONS

Scope of services

The work presented in this report is Environmental Earth Sciences response to the specific scope of works requested by, planned with and approved by the client. It cannot be relied on by any other third party for any purpose except with our prior written consent. Client may distribute this report to other parties and in doing so warrants that the report is suitable for the purpose it was intended for. However, any party wishing to rely on this report should contact us to determine the suitability of this report for their specific purpose.

Data should not be separated from the report

A report is provided inclusive of all documentation sections, limitations, tables, figures and appendices and should not be provided or copied in part without all supporting documentation for any reason, because misinterpretation may occur.

Subsurface conditions change

Understanding an environmental study will reduce exposure to the risk of the presence of contaminated soil and or groundwater. However, contaminants may be present in areas that were not investigated, or may migrate to other areas. Analysis cannot cover every type of contaminant that could possibly be present. When combined with field observations, field measurements and professional judgement, this approach increases the probability of identifying contaminated soil and or groundwater. Under no circumstances can it be considered that these findings represent the actual condition of the site at all points.

Environmental studies identify actual sub-surface conditions only at those points where samples are taken, when they are taken. Actual conditions between sampling locations differ from those inferred because no professional, no matter how qualified, and no sub-surface exploration program, no matter how comprehensive, can reveal what is hidden below the ground surface. The actual interface between materials may be far more gradual or abrupt than an assessment indicates. Actual conditions in areas not sampled may differ from that predicted. Nothing can be done to prevent the unanticipated. However, steps can be taken to help minimize the impact. For this reason, site owners should retain our services.

Problems with interpretation by others

Advice and interpretation is provided on the basis that subsequent work will be undertaken by Environmental Earth Sciences VIC. This will identify variances, maintain consistency in how data is interpreted, conduct additional tests that may be necessary and recommend solutions to problems encountered on site. Other parties may misinterpret our work and we cannot be responsible for how the information in this report is used. If further data is collected or comes to light we reserve the right to alter their conclusions.

Obtain regulatory approval

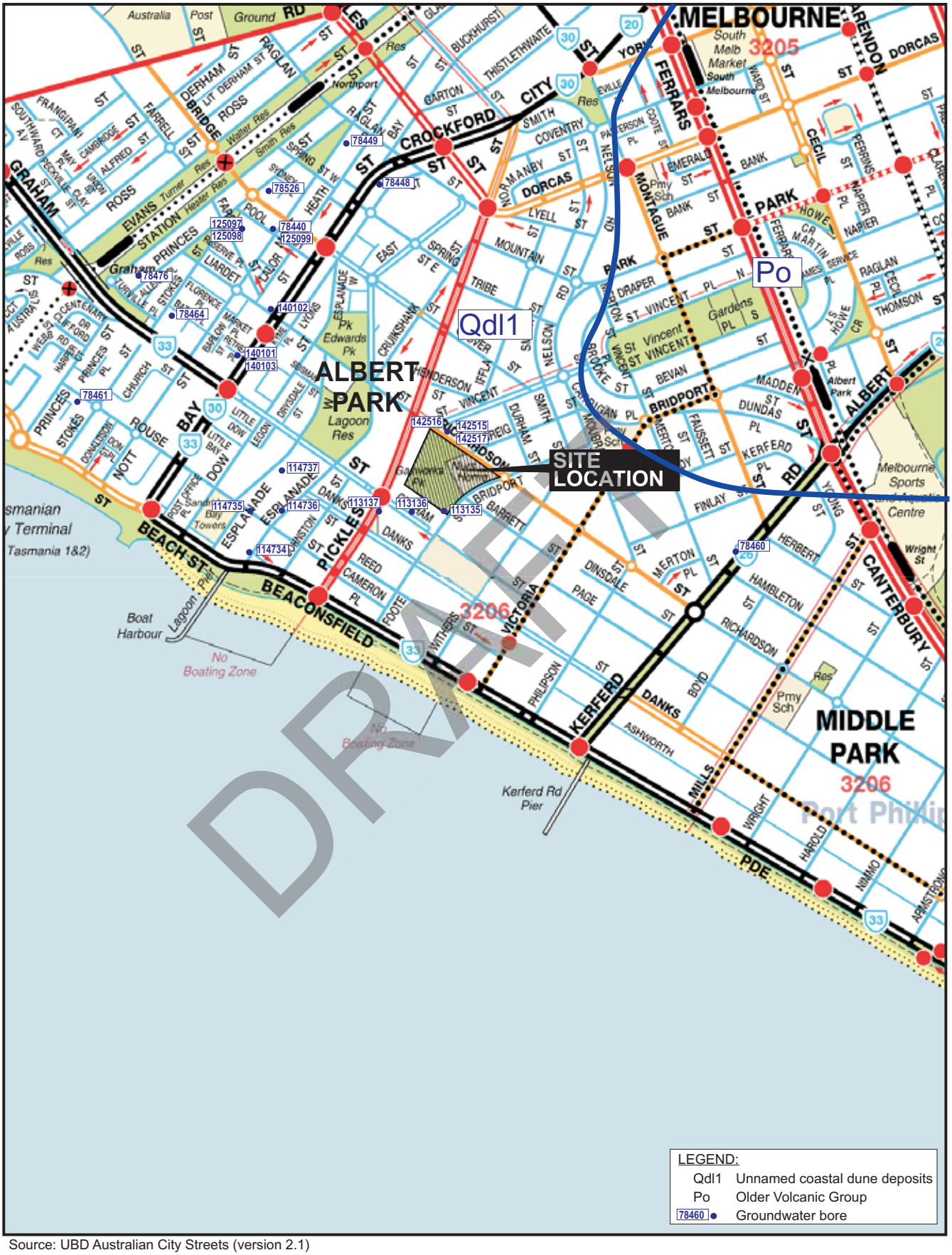
The investigation and remediation of contaminated sites is a field in which legislation and interpretation of legislation is changing rapidly. Our interpretation of the investigation findings should not be taken to be that of any other party. When approval from a statutory authority is required for a project, that approval should be directly sought by the client.

Limit of liability

This study has been carried out to a particular scope of works at a specified site and should not be used for any other purpose. This report is provided on the condition that Environmental Earth Sciences VIC disclaims all liability to any person or entity other than the client in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by any such person in reliance, whether in whole or in part, on the contents of this report. Furthermore, Environmental Earth Sciences VIC disclaims all liability in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by the client, or any such person in reliance, whether in whole or any part of the contents of this report of all matters not stated in the brief outlined in Environmental Earth Sciences VIC's proposal number and according to Environmental Earth Sciences general terms and conditions and special terms and conditions for contaminated sites.

To the maximum extent permitted by law, we exclude all liability of whatever nature, whether in contract, tort or otherwise, for the acts, omissions or default, whether negligent or otherwise for any loss or damage whatsoever that may arise in any way in connection with the supply of services. Under circumstances where liability cannot be excluded, such liability is limited to the value of the purchased service.

FIGURES



Source: UBD Australian City Streets (version 2.1)
(page 283, B8)
E 319317 N 5809245

0 500
Scale in Metres

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	**Site Location Map**		
Location:	**21 Graham Street Albert Park, Vic.**		
Client:	**City of Port Phillip**	Job No:	**210074**
Project Man:	**RO**	Scale:	**As shown**
Drawn By:	**LB**	Date:	**August 2013**
		Figure	**1**

0 20 40 60 80 100
Scale in Metres

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title: **South Melbourne Gasworks - Current Site Layout**

Location: **21 Graham Street Albert Park, Vic.**

Client: **City of Port Phillip**

Job No: **210074**

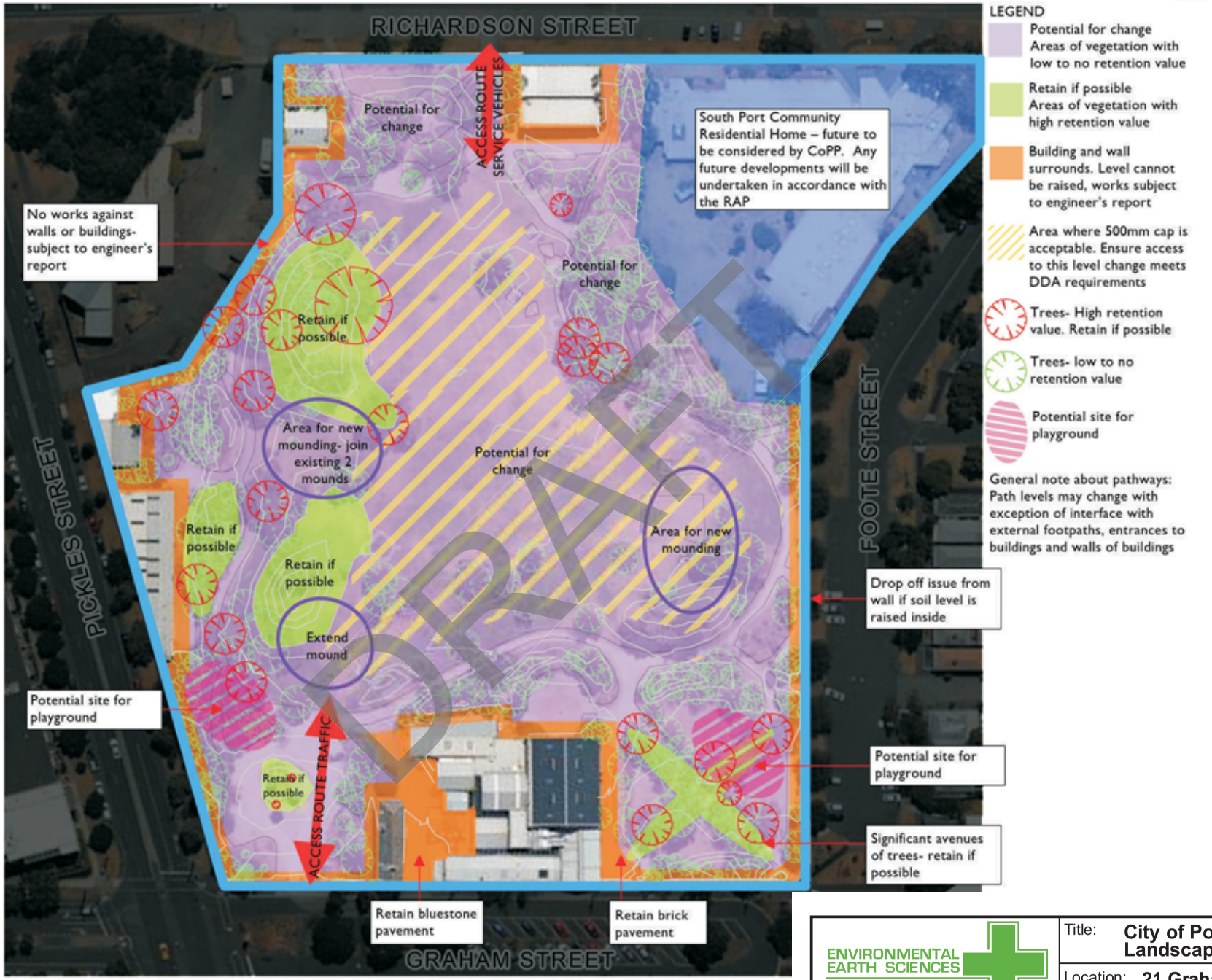
Project Man: **RO**

Scale: **As shown**

Drawn By: **LB**

Date: **August 2013**

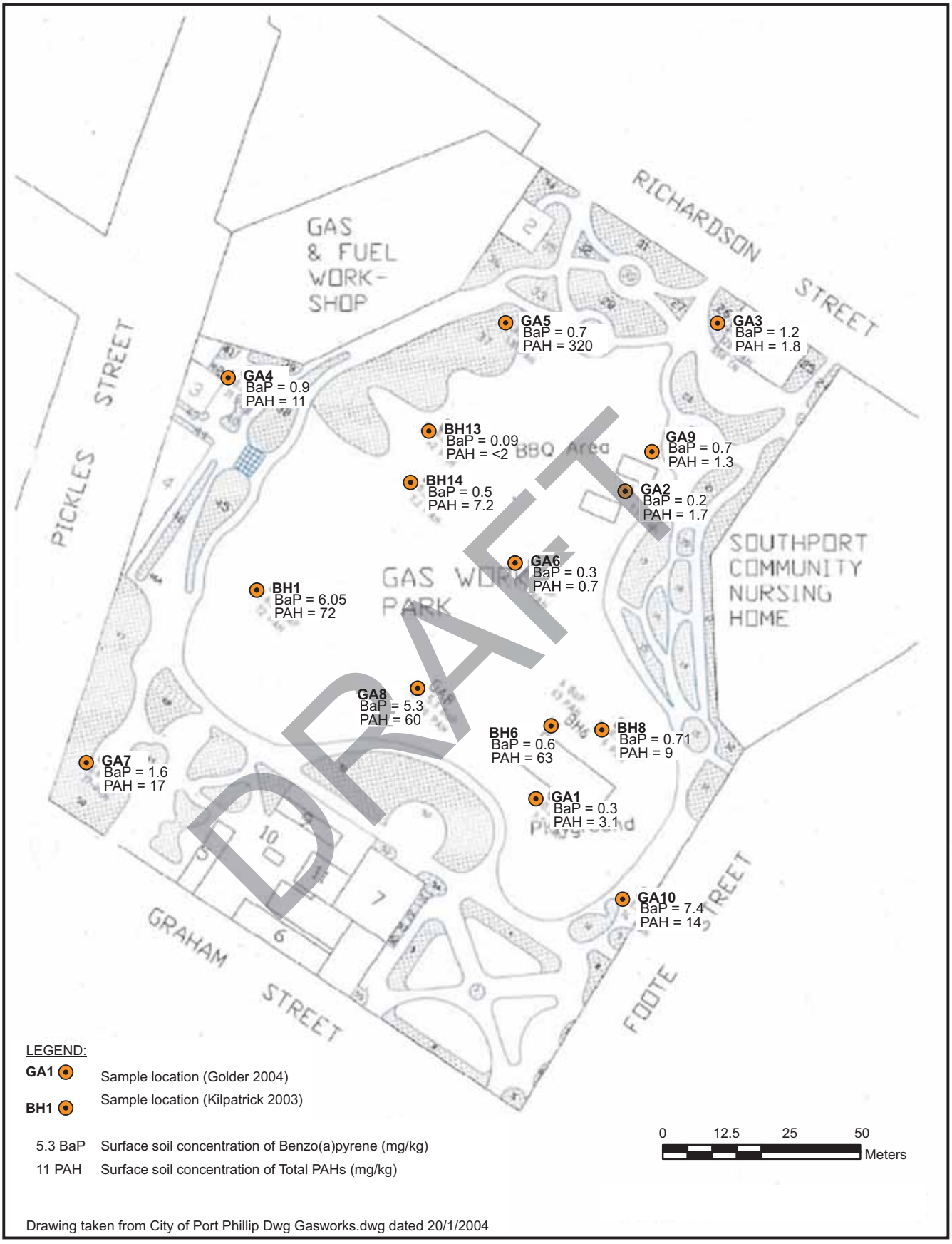
Figure **2**



ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	City of Port Phillip Landscape Plan
Location:	21 Graham Street Albert Park, Vic.
Client:	City of Port Phillip
Job No:	210074
Project Man:	RO
Scale:	As shown
Drawn By:	LB
Date:	August 2013

Figure 3

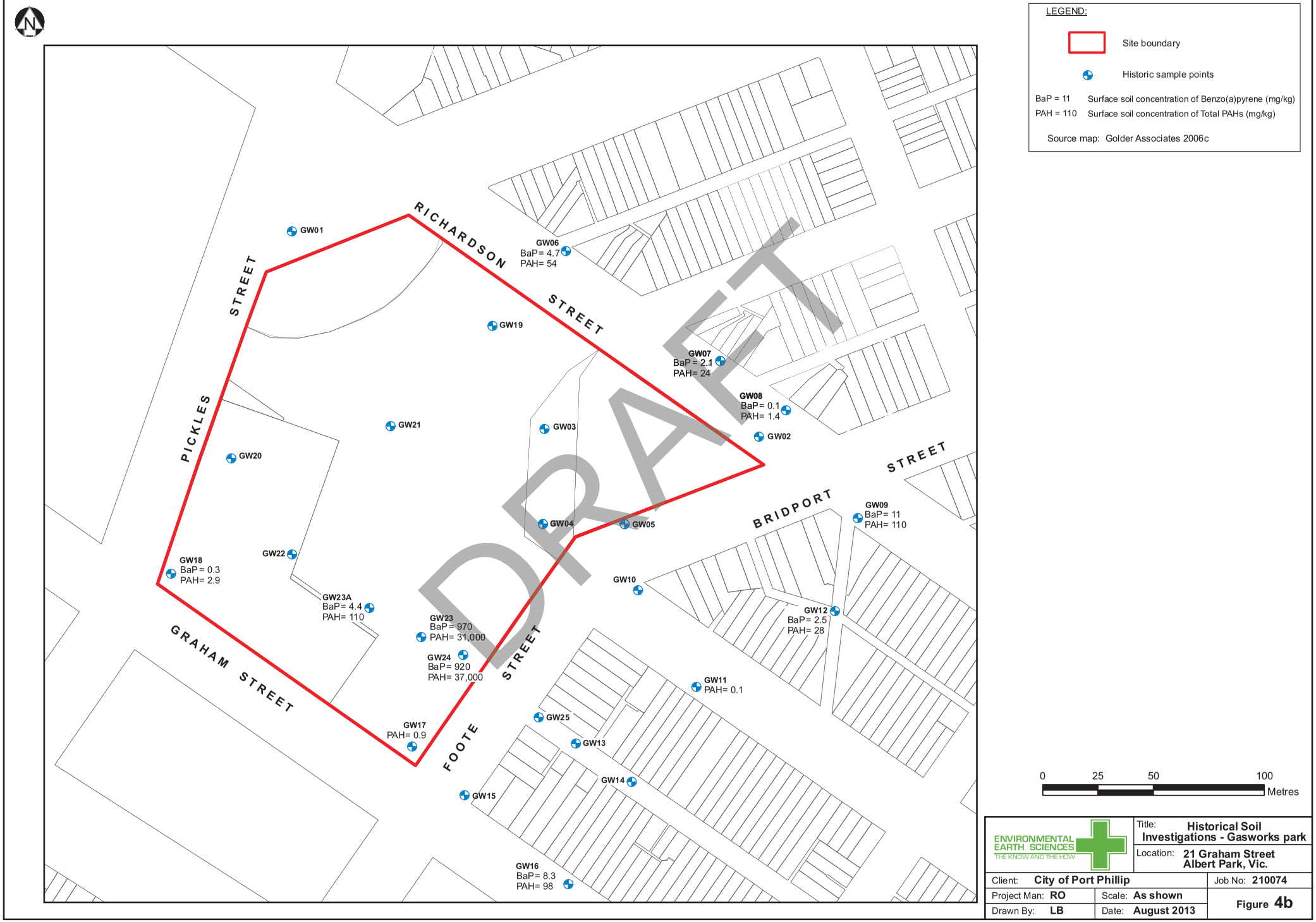


Drawing taken from City of Port Phillip Dwg Gasworks.dwg dated 20/1/2004

Source map : Golder Associates (2004)

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	**Historical Soil Investigations - Gasworks Park**		
Location:	**21 Graham Street Albert Park, Vic.**		
Client:	**City of Port Phillip**	Job No:	**210074**
Project Man:	**RO**	Scale:	**As shown**
Drawn By:	**LB**	Date:	**August 2013**
			Figure **4a**


LEGEND:
Site boundary
Historic sample points
BaP = 11 Surface soil concentration of Benzo(a)pyrene (mg/kg)
PAH = 110 Surface soil concentration of Total PAHs (mg/kg)
Source map: Golder Associates 2006c
RICHARDSON STREET
PICKLES STREET
GRAHAM STREET
FOOTE STREET
BRIDPORT STREET
GW01
GW06 BaP= 4.7 PAH= 54
GW19
GW07 BaP = 2.1 PAH= 24
GW08 BaP= 0.1 PAH= 1.4
GW02
GW21
GW03
GW20
GW09 BaP= 11 PAH= 110
GW04
GW05
GW22
GW18 BaP= 0.3 PAH= 2.9
GW10
GW23A BaP= 4.4 PAH= 110
GW12 BaP= 2.5 PAH= 28
GW23 BaP = 970 PAH= 31,000
GW24 BaP= 920 PAH= 37,000
GW11 PAH= 0.1
GW17 PAH= 0.9
GW25
GW13
GW14
GW15
GW16 BaP= 8.3 PAH= 98
DRAFT
0 25 50 100 Metres
ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW
Title: Historical Soil Investigations - Gasworks park
Location: 21 Graham Street Albert Park, Vic.
Client: City of Port Phillip
Job No: 210074
Project Man: RO
Scale: As shown
Drawn By: LB
Date: August 2013
Figure 4b

KEY:

Historic sample points

ADOPTED CRITERIA:

NEPM HIL E — BaP = 2mg/kg; PAH = 40 mg/kg

NEPM HIL D — BaP = 4mg/kg; PAH = 80 mg/kg

2.1 (bold) = Above criteria

BaP = Benzo(a)pyrene (mg/Kg)

PAH = Polycyclic Aromatic Hydrocarbons (mg/Kg)

Source map : Golder Associates - 2006d

N

0 12.5 25 Meters

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	Historical Soil Investigations - Southport Nursing Home		
Location:	21 Graham Street Albert Park, Vic.		
Client:	City of Port Phillip		Job No: 210074
Project Man:	RO	Scale: As shown	Figure 4c
Drawn By:	LB	Date: August 2013	

KEY:

- Test pits
- Borehole samples
- Site boundary
- xxx/xxx — B(a)P/PAH concentrations in mg/kg
- <5
- 5 - 10
- 10 - 20
- 20 - 50
- >50

X HILA/HILE Criteria

- Tar
- Spent oxides

Based on borelogs

NOTE:
General gasworks waste was observed at BH8

0 12.5 25 50 Meters

N

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	B(a) P / Total PAH exceedances 0.0 - 0.2m bgs
Location:	21 Graham Street Albert Park, Vic.
Client:	City of Port Phillip
Job No:	210074
Project Man:	RO
Scale:	As shown
Drawn By:	LB
Date:	August 2013
Figure	5

KEY:

- Test pits
- Borehole samples
- Site boundary
- xxx/xxx — B(a)P/PAH concentrations in mg/kg
- X HILA/HILE Criteria:
  - <5
  - 5 - 10
  - 10 - 20
  - 20 - 50
  - >50
- Based on borelogs:
  - Tar
  - Spent oxides

0 12.5 25 50 Meters

N

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	B(a) P / Total PAH exceedances 0.2 - 0.5m bgs		
Location:	21 Graham Street Albert Park, Vic.		
Client:	City of Port Phillip		Job No: 210074
Project Man:	RO	Scale: As shown	Figure 6
Drawn By:	LB	Date: August 2013	

KEY:

- Test pits
- Borehole samples
- Site boundary
- xxx/xxx — B(a)P/PAH concentrations in mg/kg
- X HILA/HILE Criteria:
  - <5
  - 5 - 10
  - 10 - 20
  - 20 - 50
  - >50
- Based on borelogs:
  - Tar
  - Spent oxides

0 12.5 25 50 Meters

N

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	B(a) P / Total PAH exceedances 0.5 - 1.0m bgs		
Location:	21 Graham Street Albert Park, Vic.		
Client:	City of Port Phillip		Job No: 210074
Project Man:	RO	Scale: As shown	Figure 7
Drawn By:	LB	Date: August 2013	

KEY:

- Test pits
- Borehole samples
- Site boundary
- xxx/xxx — B(a)P/PAH concentrations in mg/kg
- <5
- 5 - 10
- 10 - 20
- 20 - 50
- >50

X HILA/HILE Criteria

- Tar
- Spent oxides

Based on borelogs

0 12.5 25 50 Meters

N

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	B(a) P / Total PAH exceedances 1.0 - 1.5m bgs
Location:	21 Graham Street Albert Park, Vic.
Client:	City of Port Phillip
Job No:	210074
Project Man:	RO
Scale:	As shown
Drawn By:	LB
Date:	August 2013
Figure	8

KEY:

- Test pits
- Borehole samples
- Site boundary
- xxx/xxx — B(a)P/PAH concentrations in mg/kg
- <5
- 5 - 10
- 10 - 20
- 20 - 50
- >50

X HILA/HILE Criteria

- Tar
- Spent oxides

Based on borelogs

0 12.5 25 50 Meters

N

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	B(a) P / Total PAH exceedances 1.5 - 2.0m bgs
Location:	21 Graham Street Albert Park, Vic.
Client:	City of Port Phillip
Job No:	210074
Project Man:	RO
Scale:	As shown
Drawn By:	LB
Date:	August 2013
Figure	9

KEY:

- Test pits
- Borehole samples
- Site boundary
- (0.0-0.1) **330 mg/kg** (Depth) Concentration (mg/kg)

0 12.5 25 50 Meters

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	**Elevated TRH (>C10-C16) Concentrations**		
Location:	**21 Graham Street Albert Park, Vic.**		
Client:	**City of Port Phillip**		Job No: **210074**
Project Man:	**RO**	Scale: **As shown**	**Figure 10**
Drawn By:	**LB**	Date: **August 2013**	

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	**Elevated TRH (>C16-C34) Concentrations**		
Location:	**21 Graham Street Albert Park, Vic.**		
Client:	**City of Port Phillip**		Job No: **210074**
Project Man:	**RO**	Scale: **As shown**	**Figure 11**
Drawn By:	**LB**	Date: **August 2013**	

KEY:

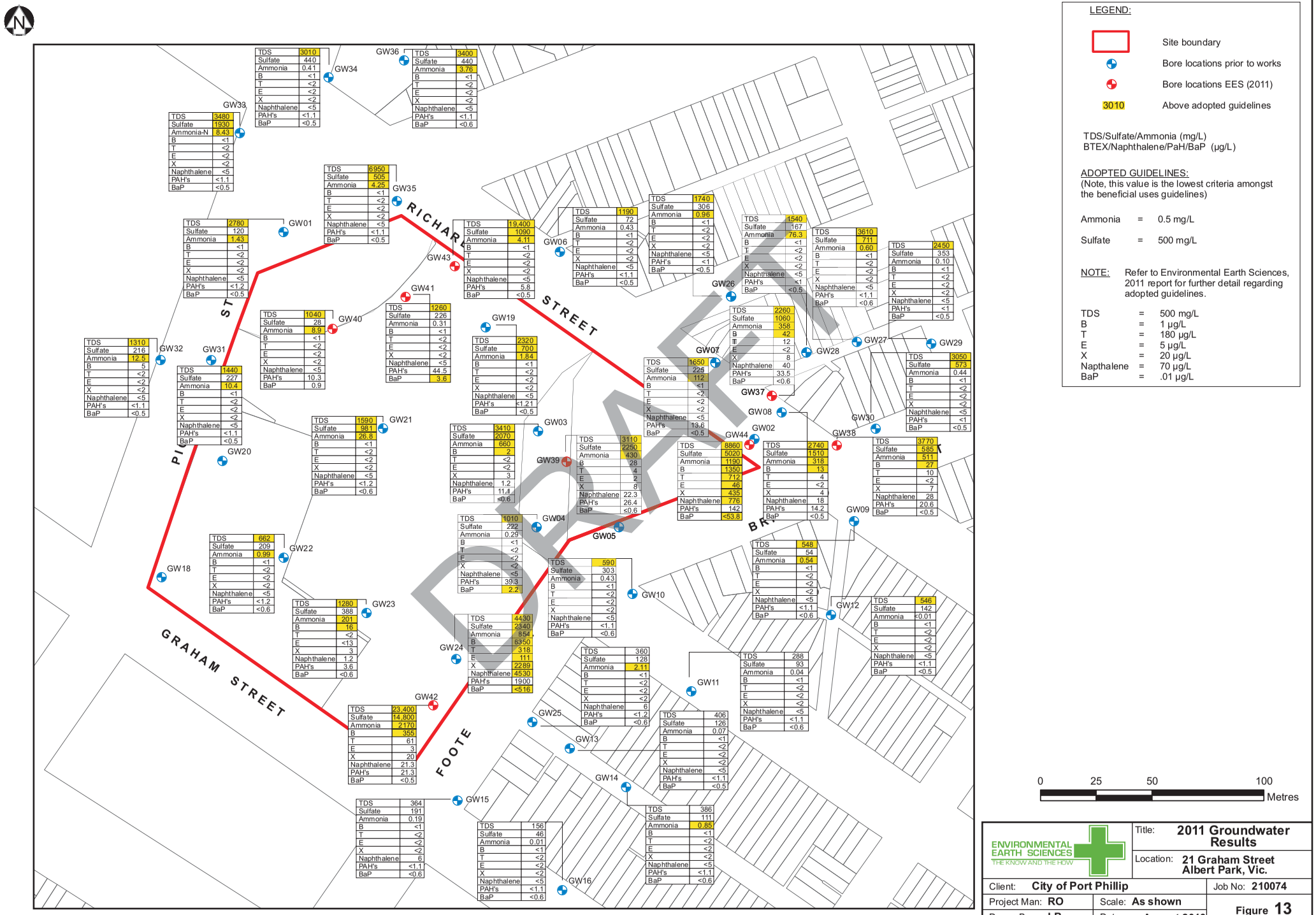
- Test pits
- Borehole samples
- Site boundary
- (0.6-0.7) **1,640 mg/kg** (Depth) Concentration (mg/kg)

0 12.5 25 50 Meters

N

ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW

Title:	**Elevated TRH (>C34-C40) Concentrations**
Location:	**21 Graham Street Albert Park, Vic.**
Client:	**City of Port Phillip**
Job No:	**210074**
Project Man:	**RO**
Scale:	**As shown**
Drawn By:	**LB**
Date:	**August 2013**
Figure	**12**


LEGEND:
Site boundary
Bore locations prior to works
Bore locations EES (2011)
3010 Above adopted guidelines
TDS/Sulfate/Ammonia (mg/L)
BTEX/Naphthalene/PaH/BaP (µg/L)
ADOPTED GUIDELINES:
(Note, this value is the lowest criteria amongst the beneficial uses guidelines)
Ammonia = 0.5 mg/L
Sulfate = 500 mg/L
NOTE: Refer to Environmental Earth Sciences, 2011 report for further detail regarding adopted guidelines.
TDS = 500 mg/L
B = 1 µg/L
T = 180 µg/L
E = 5 µg/L
X = 20 µg/L
Napthalene = 70 µg/L
BaP = .01 µg/L
RICHARDS STREET
PIER STREET
GRAHAM STREET
FOOTE
BRIDGE
GW01 GW02 GW03 GW04 GW05 GW06 GW07 GW08 GW09 GW10 GW11 GW12 GW13 GW14 GW15 GW16 GW18 GW19 GW20 GW21 GW22 GW23 GW24 GW25 GW26 GW27 GW28 GW29 GW30 GW31 GW32 GW33 GW34 GW35 GW36 GW37 GW38 GW39 GW40 GW41 GW42 GW43 GW44
DRAFT
0 25 50 100 Metres
ENVIRONMENTAL EARTH SCIENCES
THE KNOW AND THE HOW
Title: 2011 Groundwater Results
Location: 21 Graham Street Albert Park, Vic.
Client: City of Port Phillip
Job No: 210074
Project Man: RO
Scale: As shown
Drawn By: LB
Date: August 2013
Figure 13

APPENDIX A SUMMARY OF HISTORICAL REPORTS

APPENDIX A SUMMARY OF HISTORICAL REPORTS

Author and Year	Title	Scope of Work	Findings	Comments / Recommendations
Golder Associates, January 2004	Site History Review	• Site historical review of the Gasworks Park site.	• The review indicated the potential for contamination of soil and groundwater from on-site gasworks processes and from the storage/management of on-site waste. The review also found that, following a series of soil and groundwater contamination assessments, the site was declared suitable for use as a park by the EPA Victoria in 1992; and • Little remediation of on-site soil was conducted, aside from excavation of 0.5 m of contaminated fill material and replacement with "clean soil" in the south-eastern corner of the site. Other remedial works have been limited to landscaping and the placing of topsoil and clay over the site. According to the review, no record of the origin of the imported soil was found.	Further assessment and/or management were recommended.
Golder Associates, February 2004	Preliminary Assessment	• The assessment included a site inspection and laboratory analysis of 10 surface soil samples; and • High-use areas such as the playground, barbeque area and bush tucker trail was the focus of the preliminary assessment.	• Of the ten samples analysed (in addition to the six samples analysed as part of the Kilpatrick and Associates assessment [2003]), four samples reported concentrations of total PAH and benzo(a)pyrene (BaP) above applicable NEPM HIL guidelines. Additionally, surface soil data did not meet the statistical criteria as defined in the NEPM (1999); and • The investigation further also identified visual signs of contamination at the surface including, the presence of coke and spent oxide pieces in some garden beds and the playground. There was also odorous and visually contaminated ash in addition to soil stockpiled on-site from recent excavation works.	Golder Associates recommended the following short-term actions: • Addition of woodchips (at least 150 mm to 200 mm) to the playground area to provide a thicker separation from the visible coke pieces; • Off-site disposal of stockpiled soil within the southern portion of the park formed from recent maintenance works on-site; • Exposed soil to be covered with topsoil and/or reseeded; • Further maintenance and gardening activities requiring excavation were to be limited; • Suspension of all non-essential maintenance works at the park which requires sub surface works. If deep excavation works are required, then site-specific management procedures should be adopted; and • A review of garden and maintenance procedures within Gasworks Park to ensure workers were aware of the potential contamination issues and how to manage them. The report concluded that there was a need to implement a strategy for further assessment, management and remediation (as necessary), to reduce health and environmental risk associated with the site in accordance with the requirements of the CoPP Soil Contamination Management Policy.

Author and Year	Title	Scope of Work	Findings	Comments / Recommendations
Golder Associates, July 2004	Vapour and Edible Vegetation Risk Assessment	• Indoor testing for semi-volatile organic compounds (SVOC) and volatile organic compounds (VOC) and cyanide was carried out in four buildings across the site.	• Four chemicals of concern (CoC) were detected including phenol, ethylbenzene, toluene and xylene. A qualitative risk assessment of the highest recorded concentrations found no unacceptable risk to workers or residents of on-site buildings; and • Four soil gas bores were used to assess outdoor vapour risk posed by gasworks waste. Soil gas bores were located in areas of Gasworks Park with the highest potential for vapour generation. Twenty CoC were detected and concentrations were found to vary significantly between the bores assessed. A quantitative risk assessment of the highest measured concentrations took into account an exposure assessment, toxicity assessment and risk characterisation which concluded that gasworks waste on the site did not appear to be posing vapour risks to recreational users or workers of the park.	• The qualitative risk assessment of health risks posed by consumption of edible vegetables from the site, concluded that the consumption of vegetation from the site would be very infrequent so this risk was found to be negligible to very low. • The assessment also found that the uptake of PAH (the main contaminants in the soil at the site) into plant tissues is also low.
Golder Associates, July 2006	Hydrogeological Conceptual Model	• A hydrogeological conceptual model was developed for the Gasworks precinct using past hydrogeological and geological information of the area.	Golder Associates concluded the following findings: • There was significant drawdown of groundwater levels in the area of the Gasworks Park precinct caused by the South Yarra main sewer on Bridport Street; • There was significant drawdown of groundwater levels in the area of the site by the Hobsons Bay main sewer. The drawdown has been observed away from the site in areas west of Bay Street, hence, the drawdown does not appear to be just a localised; • There was some potential drawdown of groundwater levels caused by the Pickles Street sewer, particularly in the north west corner of the site; • Drawdown effect of the two main sewers adjacent to the Gasworks area was likely to have commenced after sewer construction over 100 years ago. There was evidence to suggest that drawdown effect had existed for at least 20 years; • Groundwater from Gasworks Park discharges primarily to the sewer network and was unlikely to migrate past the location of the sewers. As such, risks of contaminated groundwater flowing beneath houses to the south east of Gasworks Park and Southport Community Nursing Home was very low; • The main area of off-site groundwater flow from Gasworks Park or the Southport site that may continue beneath houses or other private land prior to discharge into the sewer system is in the north east corner of the site opposite Southport Nursing Home near GW2 and GW8; and • Groundwater modelling of the drawdown indicated likely inflows into the sewers in the order of 10 L/m/day for an assumed sewer pipe average hydraulic conductivity of around 4×10^{-9} m/s over its 0.4 m thickness.	• The seepage contributed by the Gasworks precinct along the 450 m of sewer along Bridport and Graham Streets (to Pickles Street) was estimated to be about 2300 L per day flowing into the sewer. The estimated contribution from Gasworks Park to the sewer is some 0.001% of the typical daily flow rate in the sewer in this area; and • Given modelling has estimated the sewer to have a hydraulic conductivity of the order of 4×10^{-9} m/s, repair or even blockage is unlikely to reduce this significantly, hence reduce the drawdown. Based on the relatively flat topography of the region, to "restore" the natural hydraulic gradient of the area, it would be in the order of 0.001 to 0.002 m/m towards the Bay. Based on the range of permeability's of the Brighton Group, the groundwater is estimated to move from the site towards Port Phillip Bay at very low rates of between 0.01 to 0.002 metres per year.

Author and Year	Title	Scope of Work	Findings	Comments / Recommendations
Golder Associates, July 2006	Assessment of Groundwater Risks	The assessment involved a qualitative risk assessment approach including: • An assessment of current groundwater contamination status; • An assessment of potential beneficial uses of groundwater; • An assessment of hydrogeological mechanisms responsible for current status of groundwater flow; • Review of potential risks to both human health and ecological environmental; and • Recommendations of steps to move forward in assessment and remediation.	Golder Associates concluded the following findings based on the assessment: • Groundwater under the site was classified as Segment A1, requiring the protection of all beneficial uses including: desirable potable water supply, potable mineral water supply, agriculture, parks and gardens, stock watering, industrial water use, primary contact recreation, and buildings and structures; • Contamination in background groundwater wells exceed levels protective of some A1 beneficial uses. Yield in the Brighton Group aquifer would not sustain domestic or commercial use and is unlikely to be economical; • Groundwater at the site was contaminated with common gasworks contaminants, including heavy metals, NH_3, CN, $SO4^{-2}$, total dissolved solids (TDS), PAHs and monocyclic aromatic hydrocarbons (MAHs). The main sources of NH_3, TDS and $SO4^{-2}$ appears to be in the north eastern portion of the site, whilst the main PAH and MAH sources appear to be in the south eastern and north eastern portion of the site; • The hydrogeological conceptual model indicates that discharge of groundwater from the Gasworks Park precinct is to the Melbourne Water Sewer System of which the point of discharge is thought to be the Werribee Treatment Plant; • The extremely small contribution of contaminated water from the Gasworks Park precinct to the sewer and subsequently Werribee Treatment Plant is considered unlikely to represent unacceptable risk to the environment at the Werribee Treatment Plant; • Groundwater assessment to date indicated some protected beneficial uses may be precluded by on-site groundwater contamination; • Three possible areas of off-site impact from the Gasworks Park and Southport site include: o The Alinta site; o The area between the site and the South Yarra main and Hobsons Bay main (surrounding road reserves); and o The residential area north of Richardson Street and north east of Southport Community Nursing Home between the site and the point of discharge into the South Yarra main; • Groundwater was expected to continue to discharge to the sewer systems and is unlikely to be “sealed” by Melbourne Water. If it did occur and pre-sewer groundwater flow was restored, the groundwater was estimated to take 35,000 to 175,000 years to reach Port Phillip Bay leading to significant dilution of contaminants and negligible impact to both human health and ecological receptors.	• It was recommended that further off-site groundwater investigation to the northeast; and • It was also recommended that Melbourne Water be advised regarding contaminated groundwater seepage into the sewer system and negotiations with the EPA be continued regarding potential management and remediation options of the Gasworks precinct.

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Golder Associates, July 2006	*Installation and Sampling of Additional Groundwater Monitoring Wells*	The scope of works comprised a groundwater investigation and limited soil investigation.	**Soil investigation** • Concentrations of BaP and total PAH were reported at up to 970 mg/kg and 37,000 mg/kg, respectively. TPH (C_{10}-C_{36}) concentrations were reported at up to 116,000 mg/kg. Elevated contaminant concentrations were generally confined to fill material. Elevated concentrations of BaP and total PAH were reported in natural soil at depths up to 8.2 m BGL (south of the grassed area). • The generalised soil profile within Gasworks Park comprised a layer of fill material overlying natural sands, clayey sands and sandy clays. Within the site, the thickness of fill material observed varied between 0.5 m and 3.2 m; • Near the surface, fill material generally comprised black sands with fragments of coke, bricks and glass; and • The generalised soil profile off-site to the east and south-east comprised of a shallow layer of fill material near the surface overlying natural sands and clays, with some minor bands of coarse quartz cobbles. The thickness of fill material off-site varied between 0.15 and 0.5 m. **Groundwater investigation** • A hydrocarbon odour was noted during groundwater sampling at locations GW03, GW04, GW19 (strong), GW23A and GW24; and • A hydrocarbon sheen was noted during groundwater sampling at locations GW03, GW04, GW05, GW11, GW19, GW21, GW23A, GW24 and GW25.	No recommendations provided
Golder Associates, July 2006	Review of Contamination Status – Southport Site	The scope of works included the following: • A review of historical information from previous assessment reports conducted at the site; • Sampling and chemical analysis of fill and natural materials at seven soil borehole locations and two hand auger hole	Golder Associates concluded the following findings: • The soil profile across the site was not considered suitable for redevelopment to high to medium density residential use or recreational/open space or aged care use unless remediated and/or managed; • Exceedences of lead (Pb), BaP, total PAH, TPH fraction >C9, benzene and total CN in soils were noted across the site; • potential impact on the beneficial uses of the land related to maintenance of ecosystem (plant growth) and aesthetics due to fragments of waste such as coke, ash, bricks, concrete and building rubble, and hydrocarbon odours and staining observed within site soils; • Soil pH ranges from 2.7-8.5 and suggest a potentially corrosive soil in some areas with respect to building and structures; • Fill material requires some remediation and/or management to be suitable for continued use as an aged care facility; and	It was recommended that given the issues that are common to both the Southport site and Gasworks Park, and the likely impact that redevelopment will have, it was recommended that the CoPP consider the approach to remediation and redevelopment of these sites in a coordinated manner.

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		locations; • Licensing, drilling, construction and development of four groundwater monitoring wells at the site, including one round of groundwater sampling of the four groundwater monitoring wells; • A coarse vapour survey within the newly installed groundwater monitoring wells, existing groundwater monitoring wells and the vapour probes using a photoionisation detector (PID); • Collation of the historical information and soil, groundwater and vapour data derived from the site; • Provision for the assessment of the groundwater, beneficial uses of the groundwater and its depth and flow direction; • An assessment of the data against relevant guidelines for a range of potential uses (including medium	• Groundwater impacts from past use of the area as a gasworks facility were reported with the most significant impact relating to ammonia. The source of the ammonia was indicted to be the former purifier beds historically located both on the Southport site and Gasworks Park. Further assessment of the potential migration of the identified ammonia plume to the north and east was recommended. Golder Associates also prepared an assessment to the likely minimum works to redevelop the site or maintain for current use and key risks to site redevelopment. This assessment determined that due to the groundwater contamination and the likely requirements of any works would require a planning approval or rezoning, then an Environmental Audit would be required for any redevelopment or remediation for the current use. Furthermore, key risk associated with the Southport site redevelopment was considered to be as follows: • Uncertainty to the amount and cost of remediation; • the presence of old gasworks infrastructure on-site which may increase remediation and development costs; • Redevelopment of the Southport site may trigger an overall consideration of the entire Gasworks Park precinct - having time and cost implications; • Environmental management issues and potential adverse publicity that may be incurred during remediation and redevelopment of the site; and • On-going residual liabilities for both the soil and groundwater at the site, which will need to be managed for many years.	

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		and high density residential, public open space and aged care); • A qualitative assessment of risks at the site having consideration of impacts on beneficial uses and the future use of the site; and • An outline of the assessment and remediation strategy for areas identified requiring remediation.		
Golder Associates, November 2006	Further Groundwater Investigation, North East	Groundwater sampling of the north-east wells.	Based on the findings of the additional monitoring well installation and associated sampling results, the following was concluded: • No significant change in groundwater elevations have been observed on the site between June 2006 and September 2006; • Groundwater to the north-east of Gasworks Park and Southport Community Nursing Home is inferred to be flowing west to east or south east towards the South Yarra main sewer located along Bridport Street; • Groundwater to the north east of Gasworks Park and Southport Community Nursing Home had been found to be contaminated with some heavy metals (As, Co, Cu, Pb, Ni, Zn and Se) and total cyanide. The concentrations were generally consistent amongst the off-site groundwater wells to the east and north of Gasworks Park, potentially representing background concentrations in the area; • The main contaminant of concern found during the groundwater sampling was ammonia. Golder Associates adopted the criteria of 0.01 mg/L for primary contact recreation, which is based on aesthetic considerations (corrosion of copper pipes and fittings), as no health-based guideline value is set for ammonia. It was noted that "given the depth of groundwater, the likely low yield, potential regional background quality issues, low documented groundwater use in the area, and the presence of a reticulated water system, it is unlikely that anyone in the area would drill a well to abstract groundwater for drinking purposes, irrigation, to fill a swimming pool or for stock	It is recommended that further assessment of the potential issues related to ammonia in the area of the northeast will be required as part of the regulatory process to formalise the risk assessment works undertaken to date. It was also noted that the process required to be completed will be a Section 53V audit for the premises. The outcome of such a process may still be the need for remediation of the potential ammonia sources on the Southport site and Gasworks Park and/or the need to prevent extraction and use of groundwater in the affected area in the northeast.

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			watering. As a result, the risks associated with the ammonia concentrations (and other contaminants) found in this area off site are likely to be low"; and • Concentrations of sulphate and levels of pH were indicative of background concentrations and are not considered to be as a result of contamination at the site. Furthermore, considering potential impact of groundwater on buried concrete, groundwater at the site can be classified as being non-corrosive.	
Golder Associates, October 2007	*Further Groundwater Investigation, Pickles Street Sewer*	The scope of work comprised of the following tasks: • Licensing, drilling, construction and development of six groundwater monitoring wells off- site; • One round of groundwater sampling of the six groundwater monitoring wells; • Gauging of all groundwater monitoring wells installed to the west of the South Yarra main sewer on Bridport Street; • An assessment of the groundwater data and reporting of the results; and • Updating of the groundwater hydrogeological conceptual model and associated groundwater risk assessment with the supplementary information.	Based on the findings of the additional groundwater investigation, the following was concluded: • Potentiometric groundwater levels suggests that the Pickles Street sewer was locally influencing the groundwater in this area of the site, as groundwater is moving towards the west rather than towards the south east across Gasworks Park; • It was also noted that from the installation of additional wells, the Pickles Street sewer was leaking in the area of Richardson Street (groundwater well GW34) where measured groundwater was deeper than it was closer to Graham Street. Golder Associates explained that in this area, the sewer may be leaking and that groundwater was leaking into the Pickles Street sewer, or groundwater may be flowing through the backfilled material around the sewer and into the Hobsons Bay; • There were a variety of potential sources of the groundwater contamination in the north-western portion of the Gasworks Park including Gasworks Park, the Alinta site, the former gasholder yard and laboratory site to the west of Pickles Street, and potentially other currently unidentified areas in the vicinity where gasworks fill which may have been placed as part of historical filling in the region; • Groundwater to the west and north west of Gasworks Park was contaminated with some heavy metals [arsenic (As), selenium (Se), boron (Bo) and manganese (Mn)], sodium (Na), $SO4^{-2}$, chloride (Cl), bicarbonate (HCO_3) and total CN. Concentrations were generally consistent across the off-site wells to the east and north of Gasworks Park, potentially indicating background concentrations of the area; • Golder Associates had adopted the ammonia criteria of 0.01 mg/L for primary contact recreation, which was based on aesthetic considerations (corrosion of copper pipes and fittings), as no health-based guideline value was set for ammonia. It was noted that "given the depth of groundwater, the likely low yield, potential regional background quality issues, low documented groundwater use in the area, and the presence of a reticulated water system, it is unlikely that anyone in the area would drill a well to abstract groundwater for drinking purposes, irrigation, to fill a swimming pool or for stock	Golder Associates recommended that: • This report was provided to the auditor for the site to assist in the undertaking of a s53V audit for the groundwater at the site; • A similar agreement to that proposed with Melbourne Water is sought with South East Water to inform workers of the potential contamination status of the sewer due to the ingress of contaminated groundwater; and • Further assessment of CN concentrations be undertaken in MW35 as part of future monitoring as well as additional assessment of cyanide concentrations.

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			watering. Furthermore, the likely control on groundwater being imposed by the Pickles Street sewer means that groundwater emanating from Gasworks Park in this area is unlikely to flow beneath properties where such abstraction could occur. As a result, the risks associated with the ammonia concentrations (and other contaminants) found in this area off site are likely to be low"; • Further assessment of the potential issues related to ammonia in the northeast will be required as part of the regulatory process to formalise the risk assessment works undertaken to date. It is understood at this stage that the process required to be completed will be a Section 53V audit for the premises. The outcome of such a process may still be the need for remediation of the potential ammonia sources on the Southport and Gasworks Park sites and/or the need to prevent extraction and use of groundwater in the affected area in the northeast; • Groundwater at the site can be classified as non-aggressive; • Groundwater potentiometric level collected during this assessment supports the hyrodgeological conceptual model that groundwater from the site was discharging into the Pickles Street sewer, South Yarra main sewer or Hobsons Bay main sewer and taken to Werribee Treatment Plant for treatment; • Potential risk to workers on the sewer system was considered to be low in relation to the Pickles Street sewer as the sewer is too small to be entered, and is likely to be receiving less volume of groundwater and at a lower infiltration rate than the Hobsons Bay main and South Yarra main; and • Golder Associates noted that the primary laboratory results are underestimating cyanide concentrations.	
GHD, December 2008	53v Environmental Audit – Interim Report	The initial scope of the first stage of the audit considered the following: • If groundwater quality objectives are being protected at and beyond the boundary of the site; • The likelihood of groundwater beneficial uses being realised at	The auditor identified issues requiring further assessment to resolve uncertainty and to better understand the level of risk, which included: • The extent of contamination in soil and shallow fill, and the performance requirements for capping and control of future activities; • Non-aqueous phase liquid (NAPL), particularly its presence and extent on-site, and its significance as an on-going source of vapour and groundwater contamination; • Vapours, particularly the potential for these to enter buildings; • The migration of dissolved phase groundwater contamination off-site, and the potential for use of this groundwater; and • The extent to which deeper groundwater might be contaminated and result in groundwater contamination migrating from the site.	The auditor concluded that the objectives of the further work proposed by Golder Associates will provide more information to address high uncertainty issues or present medium risk to human health or the environment. It was noted by the auditor that the further works should provide confidence that the risk will be reduced to a '*low*' or '*negligible*' level (as per the screening risk assessment criteria). While the proposals by Golder Associates infer that this will be the outcome and can be acceptable and put forward to the EPA. It was also noted that there is no indication as to the likely outcome in terms of the extent and nature of the investigation and remedial work necessary to deal with some of the more difficult issues.

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		and beyond the site; • If the beneficial uses of the land with respect to the existing land-use are protected at the site; • If the land contamination poses a risk to other environmental media and their associated beneficial uses, including groundwater at and beyond the site; and • Assessment of the adequacy of existing separation layers at SMG and associated ICMP's.	In addition, it was determined that there was a need to update the ICMP to address longer-term issues and ensure robustness of the administrative controls. The requirement for determining whether further works was required, GHD assumed that the 50 higher (i.e. medium) risk scenarios required further work to reduce the risk to '*low*' or '*negligible*' risk, and that risk scenarios ranked as '*low*' or '*negligible*' would not require clean up, management or investigative work at this time. The auditor assumed that if the risk is not able to be entirely removed (such as through removing the source) then the objective should be to reduce the higher risk scenarios to at least low or negligible risk. Golder Associates prepared a scope of works for further work to address issues of high uncertainty or that present a medium risk to human health or the environment. The proposed further works included the following: • Further assessment of groundwater/NAPL issues; • Further assessment of vapour issues; • Site capping; and • Site management. A brief outline of the proposed abovementioned works by Golder Associates is provided below, along with auditor comments regarding each proposal.	
Environmental Earth Sciences, **October 2012 V2**	April 2011Groundwater Investigations	Field work as part of this groundwater investigation (on- and offsite) included: • A groundwater gauging round, including the recording of groundwater standing water levels (SWLs), assessment of the presence of non-aqueous phase liquids (NAPL) and well serviceability	Based on the findings of the groundwater investigation, the following was concluded: • Groundwater at the site was impacted with common gasworks contaminants, including heavy metals (primarily, As, Co, Cu, Pb and Zn), NH_4+, CN, SO_4, PAHs, TPHs and MAHs. However, there is no evidence of either DNAPL or LNAPL existing onsite; • The distribution of the groundwater contamination was consistent with the former gasworks infrastructure and the physical groundwater flow system described above, in which it would be expected that the full saturated thickness of the Brighton Group would have been impacted, particularly in the vicinity of the sewers. The greatest concentrations of TDS, SO_4^{-2}, NH^4+, CN and many organics in 2011 were detected in monitoring wells screened at the base of the Brighton Group near the perimeter of the site in the vicinity of former gas purifiers towards the downgradient end of the flow system. This contamination was interpreted to have originated on site. The groundwater in the	Environmental Earth Sciences recommended the following: • The mass flux of contaminants discharging to the sewers is revisited and the associated lack of unacceptable risk to the sewer system and the treatment plant is confirmed. • A review of possible management/remediation strategies for the area of groundwater contamination to the north east of the site. This review would include consideration of the potential cost, benefit, duration, practicality, environmental footprint and risks of approaches to remediation in this area, in comparison to the current situation in which all this groundwater is captured by the sewer system. • A GQRUZ be considered that would cover the area of

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		checks; • The installation of five shallow and three deep groundwater wells; • Development of all onsite and offsite groundwater wells, including existing and newly installed wells; • The collection of groundwater samples from thirty one (31) existing groundwater wells and eight recently installed wells for laboratory analysis; and • Evaluation of aquifer properties via estimates of physical parameters by slug tests (i.e. rising and falling head tests) selectively undertaken on six groundwater wells.	Brighton Group was not interpreted to have been significantly impacted by the upwelling of higher salinity groundwater via the underlying Older Volcanics in comparison to the impacts from the Gasworks site; • The relatively low contaminant concentrations towards the centre of the site in comparison to the site perimeter could be due to less contamination originating from the central part of the site but may also reflect some flushing of the on-site flow system with less contaminated recharge since the site ceased to operate as a gasworks in 1971; • As all the groundwater migrating from the site was captured by the sewers, all the contaminants dissolved in the groundwater are also captured by the sewers. Due to the proximity of the sewers to the site boundaries, for the most part, the contaminated groundwater from the site migrates directly to the sewers without passing beneath neighbouring properties. However, there was an area to the northeast of Richardson Street where there was a plume of the NH^{4+} and SO_4^{2-} contamination that migrates beneath up to 18 properties en route to the South Yarra Sewer Main beneath Bridport Street. Relatively high concentrations of CN have also been detected in groundwater samples from this area. Therefore, although the current groundwater flow direction was interpreted to be not across, but parallel, to Richardson Street, the Gasworks site was considered likely to be the original source of this area of groundwater contamination; and • Elevated concentrations of PAHs (primarily BaP) were detected within newly installed groundwater wells in an area of very low hydraulic gradient in the northern part of the site, close to the Alinta Site. There was no identifiable source of these PAHs within this area, with the exception of buried waste. Based on the low hydraulic gradient, the likely source of PAH impacts (which was limited in its capacity to impact groundwater) and the insolubility of PAHs, it was considered unlikely that contaminated groundwater at Gasworks Park would migrate to the north west beneath the Alinta Site and pose a risk to off-site users.	interpreted gasworks-related groundwater contamination to the north east of the site. This would cover an area of approximately 20-30 private properties.
Environmental Earth Sciences, **October 2012**	Soil Capping Investigation	• Test pitting of 26 (TP1 to TP26) points was undertaken across Gasworks Park • 15 Soil borehole were sampled via a hydraulic push tube drill-rig across the Gasworks Park and Southport site	Based on visual observation during the field program, the thin layer of brown loam and the yellow-orange sandy clays, where they occur, constitute the capping layer placed over the site as part of the historical redevelopment. The capping layer is generally at least 0.5m thick where the sandy clays occur approximately half the site, but thins out to the brown loam layer across the outer edges of the site. The remainder of the site consists of the thin sandy gravel layer of the pathways, lain directly on top of impacted material, or is sealed beneath site buildings. However, the physical assessment of the capping layer has indicated that discrete exposed soil areas of the site (specifically about boreholes BH4 and BH8, and test-pit TP7) contain less than the required 0.5m of	It was also recommended that the two Interim Contamination Management Plans (ICMPs) for the site be updated to demarcate the above-listed 'hot-spots' of concern in terms of 'direct contact' exposure to coal tars in the buried gas works layer at the site. In addition measures must be included to maintain capping layer thickness and integrity. Proposed performance requirements for the capping layer include: • All exposed areas of the site are required to maintain

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			capping. PID readings were collected in the field and recorded on the soil borelogs, and ranged to maximum of 320 ppm. High PID readings (100-320 ppm) were always noted in association with strong PAH odours and visible gasworks waste in the soil profile, however, in some locations odours and gaswork waste were noted with a low PID reading. These results indicate that the gasworks waste composed of differing proportions of volatile CoPC, which have the potential to generate vapour. • Non-aqueous phase liquid (NAPL) encountered on the site was viscous tar in three sampling locations including: o Borehole BH13 showed viscous tar observed with other pyrogenic waste at 0.9 m BGL; o Test-pit TP26 showed minor amounts of viscous tar observed with other pyrogenic waste between 0.3 and 2.0 m BGL with impacts into natural material; and o Test-pit TP7 showed solid tar mixed with other gasworks waste and rubble between 0.1-1.1 m BGL and semi-viscous tar encountered between 1.8-2.7 m BGL with discrete solid tar layer 1.9-2.0 m BGL. • In addition potentially perched water with hydrocarbon sheen was encountered in test-pit TP10 at 2.4 metres. • Solid tar was encountered in the following sampling locations: o Borehole BH11 (mixed with other pyrogenic gasworks waste between 0.5-0.9 m BGL); o Test-pit TP6 (in a discrete layer between 0.8-1.1m BGL); and o Test-pit TP11 (in a discrete layer between 1.4-1.6 m BGL). • Blue spent oxides were observed mixed with other fill and gasworks waste in five sampling locations including: o Borehole BH4 (0.1-0.4 m BGL); o Test-pit TP4 (0.35-0.6 m BGL); o Test-pit TP6 (1.1-1.8 m BGL); o Test-pit TP18 (0.4-2.0 m BGL); and o Test-pit TP20 (0.8-1.0 m BGL).	either: o A vegetative cover with 0.2m underlying clean soil; or o A clean soil layer of at least 0.2m thickness underlying a pathway, topsoiled garden bed, or mulched or covered playground; • Portions of the site not complying with the cap thickness requirements need to be remediated and validated for chemical quality of the cap and thickness of clean soil above gas works waste; • Any maintenance or other excavation works on the site need to refer to the Interim Contaminant Management Plan (ICMP) for 'hot-spot' locations. Any works required to excavate soil in hot-spots (to and beyond the depth of gas works waste impact) need to be managed and supervised under the ICMP requirements. The ICMP may need upgrading in this regard; • Following completion of any maintenance/ excavation works in hot-spot areas (or other locations where coal tar gas works waste was identified), soil should be replaced in the order it was removed, and a physical and chemical assessment of soil profile undertaken following reinstatement; and • The ICMP requires a register of works to track the above required undertakings, as they occur. In this way the integrity of the cap will be more confidently assured. • So long as the above recommendations are complied with, and the conclusions of this work indicate beneficial uses and receptors are protected, soil at the site (at the locations assessed) is considered to be in an appropriate chemical condition for on-going current uses.

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Environmental Earth Sciences, **November 2012**	Indoor Ambient Air Vapour Investigation	The scope of works consisted of: • Site inspection to evaluate building characteristics that might influence vapour sampling and potential cross contaminating indoor sources of vapours; and • Two rounds of indoor ambient air sampling events, using USEPA Method TO-15, in winter and summer seasonal conditions	Detectable concentrations of vapours measured at the site by Environmental Earth Sciences were low and appear largely due to indoor cross contaminating sources noted to be within the building such as paints, solvents, thinners, glues, resins etc. Only benzene, naphthalene and trimethylbenzene concentrations in three separate locations exceeded initial screening criteria, and only benzene exceeded the exposure adjusted criteria. Environmental Earth Sciences consider that the concentrations were attributable to indoor sources rather than from as a result of gasworks waste at the site. The vapour intrusion exposure pathway appears to be mitigated by the following factors: • Building design, including ventilation, building height and subsurface penetrations; • Radial flow of impacted groundwater outwards away from buildings due to drawdown from sewers; • The low likelihood of gasworks waste buried in soil beneath or in close proximity to original gasworks buildings; and • Natural site setting with depth to groundwater greater than 7m in sandy clay soils. Based on the results of this assessment, Environmental Earth Sciences considered that any sub-surface vapour intrusion at the site appears to be negligible and unlikely to result in a chronic unacceptable health risk to building users. On this basis, remedial options and / or management systems were not considered necessary at this time to manage vapour intrusion into site buildings. This conclusion was provisional upon site land use and buildings remaining unaltered.	No recommendations provided