City of Port Phillip

Section 53V Environmental Audit

Gasworks Site, Albert Park

September 2014

Executive summary

Table 1 Summary of audit information

Summary information required	
EPA file reference number	68288-1
Auditor	Dr Peter Nadebaum
Auditor term of appointment	16 May 1990 to 29 September 2015
Name of person requesting audit	Mr Sam Hewett, Manager Asset Services, City of Port Phillip (CoPP)
Relationship to premises/location	
Date of request	17 August 2010
Date EPA notified of audit	19 August 2010
Completion date of the audit	12 September 2014
Reason for audit	Voluntary
Description of activity	
EPA region	Metro
Dominant – Lot on plan	
Additional – Lot on Plan(s)	
Site/premises name	Gasworks Arts Park and Southport Site
Building/complex sub-unit No.	
Street/Lot – Lower No.	
Street/Lot – Upper No.	
Street Name	
Street type (road, court, etc.)	
Street suffix (north, south, etc.)	
Suburb	Albert Park
Postcode	
GIS coordinate of site centroid	
Longitude / Northing (GDA94)	5809661.166524 N
Latitude / Easting (GDA94)	319365.453500 E

Summary information required	
Members and categories of support team utilised	Eric Friebel (human health risk assessments) Paul Bolger (hydrogeology) Barry Mann (hydrogeology)
Outcome of the audit	Improved containment and/or soil remediation is required. Ongoing groundwater monitoring is required.
Further works or requirements	Decision to be made as to whether the capping strategy has an acceptable level of risk, noting the potential for additional works to be required if the deep sewers are repaired. Decision to be made as to whether further soil sampling will be carried out to gain a better understanding of the extent of soil contamination and where capping is or is not required. If further sampling is not carried out, then remedial works should be implemented. Update RAP to define the final remedial works. Auditor to verify the RAP. Implement RAP. Auditor to verify implementation of RAP.

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Surrounding land use	

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Acronyms

Acronym	Definition
ACM	Asbestos containing material
ANZECC	Australian and New Zealand Environment and Conservation Council - Water Quality Guidelines for Fresh and Marine Waters
ASRIS	Australian Soil Resource Information System
ASS	Acid sulfate soils
BTEX	Benzene, toluene, ethylbenzene and xylene
BaP	Benzo(a)pyrene
CMP	Contaminant Management Plan
DSE	Former Department of Sustainability and Environment
EES	Environmental and Earth Sciences Pty Ltd
EIL	Environmental investigation level
ESL	Environmental screening level
enHealth	Environmental Health Committee
EP Act	Environment Protection Act 1970
EPA Victoria	Environment Protection Authority Victoria
GHD	GHD Pty Ltd
Groundwater SEPP	State Environment Protection Policy (Groundwaters of Victoria)
HIL	Health investigation level
HSL	Health screening level
ICMP	Interim Contamination Management Plan
IWRG	Industrial Waste Resource Guidelines
JSEA	Job safety and environment analysis
Land SEPP	State Environment Protection Policy (Prevention and Management of Contamination of Land)
mAHD	Metres Above Australian Height Datum
mbgl	Metres below ground level
NEPM	National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1)
OCP	Organochlorine pesticide
OPP	Organophosphate pesticide
PAH	Poly-aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PPE	Personal protective equipment
SWL	Standing water level
TDS	Total dissolved solids
TPH	Total petroleum hydrocarbons
TRH	Total recoverable hydrocarbons
SEPP (Waters of Victoria)	State Environmental Protection Policy (Waters of Victoria)
SVOCs	Semi-volatile organic compounds
VOCs	Volatile organic compounds

1. Introduction

1.1 Background

In 2007, City of Port Phillip (CoPP) requested that Dr Peter Nadebaum undertake an environmental audit of the former South Melbourne Gasworks site, located in Albert Park, Melbourne (refer Figure 1). The South Melbourne Gasworks site comprises two parts: the Gasworks Art Park (herein referred to as the Gasworks Park), and the Southport Community Nursing Home (referred to as the Southport site). Collectively these two parts are referred to throughout this report as 'the site'. CoPP initiated the audit voluntarily, and the EPA has not issued a Notice for the site.

This report outlines the results of an assessment of risk as part of an audit carried out under Section 53V of the *Environment Protection Act 1970,* for the site. The audit was undertaken in two stages. The first stage was completed in 2008, reported as *Section 53V Environmental Audit – Interim Report, Gasworks Site, Albert Park,* December 2008 ((GHD 2008) herein referred to as the 'Interim Audit', attached as Appendix A)[1]. The second stage of the audit commenced in August 2010: this audit report documents the findings of the second stage of the audit.

1.2 Interim audit

The Interim Audit involved a preliminary assessment of the risks associated with soil and groundwater contamination at the site, based on the information available at the time[2], with a view to determining what further investigation and remediation was required.

The interim audit included a consideration of:

- Whether or not groundwater quality objectives were being protected at and beyond the boundary of the site;
- The likelihood of groundwater beneficial uses being realised at and beyond the site;
- Whether or not the beneficial uses of the land with respect to the existing land use were protected at the site, including:
  - Whether the site could continue to be managed and used in its present manner until remediation or management strategies (such as an additional separation or capping layer) could be implemented; and
  - The risk of any possible harm or detriment to land caused by past gasworks operations and activities at the site;
- Whether or not the beneficial uses of the land with respect to the proposed land use were protected at the site; and
- Whether or not the land contamination posed a risk to other environmental media and their associated beneficial uses, including the use of groundwater at and beyond the site.

The Interim Audit also included a review of two Interim Contamination Management Plans (ICMPs) in place for the site, one being for the Gasworks Park and one for the Southport site, and consideration as to whether the site could continue to be used and managed in its present

[1]) Interim Audit EPA CARMS Reference was 33458-9. A further stage of the 2008 audit was initially proposed (EPA CARMS Ref. 33458-10) to assess the risk of possible harm or detriment to land caused by past industrial activities at the site, however this was not undertaken as further assessment works were required. Both 3345-9 and 33458-10 were terminated on 20 December 2010.

[2] The information available at the time of the Interim Audit included a series of soil and groundwater investigations undertaken by Golder Associates Pty Ltd (Golder) between 2004 and 2007.

form until further remediation, revised management plans, and/or master plans were designed and implemented.

At the time of the Interim Audit, plans for the site's redevelopment had not been decided and risks to proposed future land uses were therefore evaluated on the basis of the land use at the time continuing unchanged.

The Interim Audit identified a number of scenarios that potentially posed a risk of harm on and offsite, including:

- Migration of volatile emissions into onsite buildings and structures, including residential buildings, as well as excavations;
- Contact by persons with contaminated soil and gasworks waste that may be on the surface of the site;
- Contaminated groundwater being extracted for use at the site;
- Contaminated groundwater leaving the site and being extracted offsite for domestic, irrigation and recreational uses; and
- Contaminated groundwater (and non-aqueous phase liquid (NAPL)) entering nearby sewers and potentially giving rise to emissions and direct contact risk for workers.

Several issues requiring resolution to better understand the level of risk were identified, including:

- The extent of contamination in soil and shallow fill, and the performance requirements for capping and control of future activities;
- NAPL, particularly whether present, and if present its extent and significance as an ongoing source of vapours and groundwater contamination;
- Vapours, particularly the potential for vapours 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.

Additionally it was determined there was a need to update the ICMPs to address longer-term issues and ensure robustness of the administrative controls.

Golder (assessors prior to, and during the Interim Audit) prepared a scope for further works to address issues that were found to be either of higher uncertainty, or risk to human health or the environment. The auditor reviewed and commented on the proposed scope of works; however, it is understood the works were not subsequently implemented.

1.3 This audit

Following completion of the Interim Audit, further soil and groundwater assessment works were undertaken by Environmental Earth Sciences (EES) in order to address the issues identified in the Interim Audit, and the second stage of the audit (documented in this report) was completed. The second stage of the audit involved a review of the level of risk posed to human health and the environment at and surrounding the site; this considered the additional soil and groundwater information available, and also considered the situation that would result if proposed remedial and management actions were to be implemented at the site.

This report outlines the findings of the second stage of the audit, and includes:

- A brief summary of the findings of the Interim Audit;
- A review of reports prepared by EES which provide further information on contamination present in soil at the site, groundwater contamination at and in the vicinity of the site, the adequacy of the existing soil capping layer, and an assessment of risk to occupants of onsite buildings arising from migration of subsurface contamination;
- A review of the screening risk assessment undertaken as part of the Interim Audit in light of the additional information now available, and the proposed remedial actions;
- A review of a Remediation Action Plan (RAP) prepared by EES which provides a strategy for capping the site and ongoing monitoring of groundwater;
- A review of Contaminant Management Plans (CMPs) for the Gasworks Park and Southport site, prepared by EES for ongoing management of contamination at the site, post-remediation; and
- Recommendations for further work and/or ongoing management.

1.4 Purpose of this report

The purpose of this report is to present the findings of an assessment of risk undertaken as part of an audit carried out under Section 53V of the *Environment Protection Act 1970,* for the South Melbourne Gasworks Site (the site).

1.5 Scope and limitations

This environmental audit report ("Report") has been prepared in accordance with Part IXD of the Environmental Protection Act 1970. The Report represents the Auditor's opinion of the risks that soil and groundwater contamination at the Site poses to beneficial uses of land, groundwater and surface water at the site and off site, at the date of completion of the audit. The scope of this audit is limited to the specific scope as defined in this Report and the Auditor makes no other statement, warranty, comment in respect of the environmental conditions, risks or otherwise in relation to the site beyond this defined scope in this Report.

This Report:

1. has been prepared by Dr Peter Nadebaum of GHD Pty Ltd ("GHD") and his team as indicated in the appropriate sections of this Report for City of Port Phillip (CoPP);
2. may be used and relied on by City of Port Phillip;
3. may be used by and provided to EPA for the purpose of meeting statutory obligations in accordance with the relevant sections of the Environment Protection Act 1970;
4. may be provided to other third parties but such third parties' use of or reliance on the Report is at their sole risk because of, and subject to, the uncertainties associated with this audit as noted in the following paragraphs and in this Report; and
5. may only be used for the purpose as stated in Section 2 of the Report (and must not be used for any other purpose).

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the Report are excluded unless they are expressly stated to apply in this Report.

The services undertaken by the Auditor, his team and GHD in connection with preparing this Report were undertaken in accordance with current professional practice and by reference to

relevant environmental regulatory authority and industry standards in accordance with section 53V of the Environment Protection Act 1970.

The opinions, conclusions and any recommendations in this Report are based on assumptions made by the Auditor, his team and GHD when undertaking the audit and preparing the Report. The assumptions are specified throughout this Report.

In preparing the audit, the Auditor and his team have considered the available information in reaching a conclusion regarding the level of risk to beneficial uses; and this has required consideration of information that in some cases was not capable of being verified within the time scale of the audit, is of a nature that does not allow it to be quantified, or had a high degree of uncertainty with respect to magnitude of effect and likelihood of effect. In some cases information was not available and was not able to be obtained within the time scale of the audit. Where information was not available or was uncertain, the Auditor has made a judgment regarding the situation that, in his opinion, is likely to apply. The assessment of risk requires a consideration of the magnitude of effect and the likelihood that an effect of that magnitude will occur; this is inherently uncertain and depends on the significance that persons place on the effect, and other persons may reach an alternative conclusion as to the level of risk that applies. Because of these factors, caution is required in the use of the information in this Report, and persons referring to, relying on or using in any way the conclusions of this Report should make their own assessment and seek independent advice from persons with the relevant expertise in the field to satisfy themselves that they understand the underlying information and level of uncertainty, and the level of risk that they would assign, which may differ from the level of risk that the Auditor has assigned.

Subject to the paragraphs in this section of the Report, the opinions, conclusions and any recommendations in this Report are based on conditions encountered and information reviewed at the time of preparation of this Report and are relevant until such times as the site conditions or relevant legislation changes, at which time, GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with those opinions, conclusions and any recommendations.

The Auditor and GHD have prepared this Report on the basis of information provided by CoPP and its consultants Golder Associates (Golder) and Environmental Earth Sciences (EES); the Auditor and his team have carried out checks of samples of this information in accordance with industry practice; this checking did not extend to all information; and the Auditor and GHD have not carried out field work to independently verify the information. Where the Auditor considered that the level of uncertainty or errors in the information could lead to a significantly different finding, the Auditor has made recommendations for further work to be carried out in the future to resolve the uncertainty. Because of this, there is uncertainty in the conclusions regarding the risk to beneficial uses and the Auditor and GHD expressly disclaim responsibility for errors that have arisen because of uncertainty in the information.

This Report should be read in full and no excerpts are taken to be representative of the findings of this Report.

2. Scope of the audit

2.1 Site description

The audit area (the site) covers an area of approximately 3.21 ha[3] within Albert Park (see Figure 1). The main part of the site (2.67 ha), is being used as a park (Gasworks Park) and part of the north east corner (0.54 ha) is occupied by the Southport Community Nursing Home (Southport site). The Gasworks Park consists of grassed and landscaped areas, bands of mature trees, seating areas, a playground, a small wetland and gravel tracks. There are 11 buildings on Gasworks Park (Figure 2), some of which were former gasworks buildings that were retained as part of the redevelopment. The buildings are now used for arts-related activities (i.e. sculpture, ceramics, a bookshop, café and a theatre). The grassed areas are used for recreation, and include a dog-off-leash area.

The Southport site was established on the north east corner of the site in the 1980s. A brick building covers most of the Southport site, with the remainder established grass and landscaped areas.

The site is bound by Graham Street to the south east, Pickles Street to the west, Richardson Street to the north east, and Foote/Bridport Street to the south east. Neighbouring land uses at the time of the audit include:

- Low density residential houses over Richardson and Foote Streets to the north and east respectively;
- An Alinta-owned site located near the corner of Richardson and Pickles Streets, forming the north eastern boundary of the audit area. The Alinta site is used as a gas and fuel workshop;
- High-density apartments on the eastern side of Pickles Street;
- High density residential townhouses south of Graham Street; and
- Albert Park Secondary College bounded by Foote Street and Graham Street.

CoPP intends to continue use of the Gasworks Park as a community park. It is recognised as an important asset to the community, with the intensity of use increasing as further high density residential properties are constructed in the area. At the time of this audit CoPP is in the process of planning works to upgrade the condition of the Park. This includes the preparation of a draft conceptual landscape plan for the Park (the Park Plan), which was released for community consultation in April 2014. The Draft Park Plan incorporates requirements for providing an adequate capping layer, or alternative remedial measure across the site (refer Section 5.4 for further detail), and takes into consideration public feedback gathered during previous community consultation. The Draft Park Plan proposed that soil remediation be undertaken in a single event, which would involve closure of the park for approximately 12 months, removal of all existing vegetation including trees, removal of infrastructure, and placement of 0.5 m capping soil across the site.

Following the release of the Draft Park Plan, CoPP undertook extensive community consultation (until 21 July 2014). At the time of completion of this audit, the consultation period had closed, with community feedback showing considerable concern in relation to several issues, including (but not limited to) retention of mature trees and vegetation, the disruption caused by

[3] EES has referred throughout its reports to a total site area of both 3.43 ha and 3.21 ha. The discrepancy is due to incorrect inclusion of the Alinta site (area 0.22 ha) which is not part of the audit are. The correct site area is 3.21 ha, as shown on Figure 2.

remediation to park users by closure of the park for a 12 month period, and whether the levels of contamination warranted remediation. This is discussed further in Section 5.4.

A plan for the future use of the Southport site has not been finalised; the auditor understands that it is to remain as a nursing home for the short term.

It is understood that during the redevelopment of the Gasworks Park, the boundary between the Southport site and Gasworks park (currently an arbitrary boundary) will be adjusted to be consistent with the Certificate of Title boundaries (refer Figure 2). The auditor notes that in many of EES' reports (details provided in Section 4.1) the site boundary was incorrectly shown to include the Alinta site to the north. The correct audit boundary, which is defined by a survey plan provided by CoPP, is shown on Figure 2.

2.2 Review of site history

The following site history information has been summarised from the Interim Audit report.

The Gasworks Site was used for gas manufacturing from 1873 until decommissioning in 1955. The Southport Site was established in 1981. It is understood that in 1982 the northern two thirds of the site was landscaped and grass cover was established forming Gasworks Park, with no additional remediation being undertaken. The landscaping appears to have comprised the placement of clay and topsoil; however, records have not been found that detail the depth and extent of this cover.

The presence of tar was noted in the southeast corner of the site. This area remained fenced off from the park awaiting EPA approval of an appropriate remediation proposal. Subsequently EPA advised the City on 28 November 1991 of the following requirements for landscaping of Foote/Graham Street area:

1. Soil is removed to a nominal depth of 0.5 m and disposed to an EPA licensed landfill;
2. Agriculture drainage is installed to prevent pondage of water and minimise the migration of contaminants from this area;
3. The excavation is backfilled with clean fill (this need not be impervious clay); and
4. Vegetation needs to be selected that will ensure root growth will not penetrate the base of the old purifiers.

It is understood that the top 0.5 m of fill was removed from the Graham/Foote Street area by February 1992 and disposed offsite. The fill was replaced with approximately 0.3 m of soil from unknown origin[4]. Minutes of the last Gasworks Site Contamination Steering Committee on 11 February 1992 indicate that the remediation works were scheduled for completion in July 1992. It is assumed that the works were completed as proposed by EPA.

2.3 How the scope was defined

An environmental audit of an activity can range from a full assessment of large industrial premises to a focussed assessment of a small component of an activity. EPA Publication 952.4 *"Environmental Auditor Guidelines for the Preparation of Environmental Audit Reports on Risk to the Environment"* (EPAV, April 2013) provides guidance to environmental auditors undertaking an environmental audit pursuant to Section 53V of the *Environment Protection Act 1970*. The auditor referred to the information contained in this guideline to establish the scope of the audit for this site.

[4] Historical reports indicated fill was replaced with 0.5 m 'clean fill', however EES site capping investigations undertaken in January 2011 identified 0.3 m of clay (EES 2014A)

The outline for the scope of the audit was based on:

- The initial Project Brief prepared by CoPP and provided to GHD prior to the auditor being engaged;
- The Interim Audit report; and
- Communications through the course of the audit (written and verbal, as indicated below) with EPA and site stakeholders.

The audit scope was presented to EPA as a draft in November 2012 (*City of Port Phillip, Gasworks Site, Albert Park, 53V Environmental Audit Scope, DRAFT,* November 2010, herein referred to as the 'draft scope' (GHD 2010, attached as Appendix B)). The auditor then met with EPA in December 2010 to provide an outline of the site issues and the draft scope. The auditor explained the intent of the further work being undertaken by CoPP and EES was to obtain a better understanding of the contamination issues of the site, and to determine the remediation and management controls that would be required to make the site safe (i.e. acceptable risk) for its continued use. EPA indicated verbally that the audit scope and proposed approach were acceptable[5].

The audit was initially intended to be conducted in two stages, with the intent to lead to a RAP and/or an upgraded Contaminant Management Plan (CMP, to replace the ICMPs. Subsequent to the development of the draft scope, between January 2011 and June 2011, EES undertook soil, ambient air and groundwater assessments to provide further information on the contamination status of the site, and to address data gaps identified in the Interim Audit. Broadly, these investigations focussed on three aspects of contamination: site (soil) capping; vapour (indoor air quality); and groundwater. Details of the reports by EES reviewed as part of this audit are provided in Section 4.1.

Several meetings have been held with EPA during the course of the audit, in which variations to the initial scope and intended future direction of the audit were discussed. In March 2013 the auditor met with, and provided a briefing paper to EPA outlining the site status and proposed remediation/management approach[6]. Containment of contamination was identified as being likely to be the preferred option, subject to various requirements (e.g. that safe containment could be assured for the long term, risks associated with groundwater were acceptable, etc.). Four remediation and management actions were identified; these included upgrading the cap, revising the ICMPs, development of a Groundwater Quality Monitoring Plan (GQMP) and undertaking groundwater monitoring, and verification of the remediation and plans by the auditor. The auditor requested confirmation from EPA that the approach being applied to decision making was consistent with EPA's requirements, that the consideration of competing factors and reaching a balanced outcome was appropriate, and the option of achieving safe containment of residual contamination and retention of the park as a heritage precinct was not precluded nor inconsistent with EPA's polices and guidance.

EPA responded in April 2013[7] acknowledging that containment could be an acceptable and preferred management approach with the following actions: improving the capping layer so the site would be suitable for long term use as a park; reviewing and revising the existing SMP, and preparing and implementing a GQMP. EPA recognized the audit report (this report) would be completed once the RAP had been finalised, and that this report would outline the key

[5] EPA was to provide written confirmation of acceptance of the draft scope, however this was not received.

[6] Meeting with EPA 4 March 2013 and GHD letter to EPA, 21 March 2013, *South Melbourne Gasworks, Briefing paper on site status and proposed remediation / management approach",* ref. 31/26548/220084.

[7] EPA letter to GHD was dated 4 April 2014: this was considered a typographical error, with the correct date 4 April 2013, *South Melbourne Gasworks – Proposed Remediation/Management Approach,* ref. 68288-1.

requirements for the SMP and GQMP and any additional recommendations. EPA advised that the approach outlined by the auditor was appropriate and consistent with EPA's requirements.

In July 2013 the auditor again met with CoPP and other stakeholders including DTF and DEPI to discuss the findings of this further capping, vapour and groundwater assessments, and to outline the strategy for remediation at the site. It was noted containment was the preferred approach, and discussion was held regarding integration of remediation with proposed landscape redevelopment works. It was noted the Gasworks Park would remain as open space in the indefinite future, as Council saw that providing for open space was an important requirement. The future of the Southport site was not known, though a proposal had been made to move the nursing home.

Following the release of the Draft Park Plan for community consultation in April 2014, further meetings[8] were held with CoPP, and CoPP and EPA, to discuss concerns raised by the community in relation to the proposed remedial approach of capping the site with 0.5 m soil in a single event, which would necessitate the removal of all vegetation from the site. During these meetings, alternative approaches were discussed including further soil testing in treed areas to determine whether there were areas that could be retained (i.e. with negligible levels of soil contamination), and/or fencing or otherwise restricting access to (e.g. planting out) treed areas with higher levels of contamination. These options have been considered in the Auditor's recommendations.

2.4 The objectives of the audit

The objectives of the audit are to:

- Determine the risk to beneficial uses of the site with respect to the existing and proposed future land use;
- Determine the risk to on-site and off-site beneficial uses of groundwater with respect to existing and proposed future land use;
- Evaluate whether the proposed remedial and management actions are sufficient to reduce the risks to an acceptable level; and to
- Provide recommendations for further work that may be necessary to reduce the risk to an acceptable level.

2.5 The activities and components of the activities to be considered

The objective of a Section 53V audit is to provide an auditor's assessment 'in relation to the risk of any possible harm or detriment to a segment of the environment caused by any industrial process or activity, waste, substance, or noise' (*Environment Protection Act 1970).* In the case of the audit site, a number of activities are subject to audit, including:

- The former use of the site for gas-making, and the associated land and groundwater contamination that has resulted from this activity at the site;
- The current site contamination management arrangements; and
- The management arrangements that are proposed for the ongoing use of the site.

[8] Meetings with CoPP and EPA held on 22 April 2014 and 30 July 2014, and meetings with CoPP held on 18 and 19 August 2014.

2.6 The segment of the environment to be audited

The geographical extent of the segment of the environment on which the former gasworks activities took place, and hence which formed a source of contamination, is essentially the land within the boundary of the Gasworks Park and Southport site (the site). This area is described in Table 2 and presented on Figure 2[9].

The segment audited includes the site, the area in the immediate vicinity of the site where it is possible for groundwater with contamination arising from the site to adversely affect the use of groundwater, and the sewerage system that acts as a sink for groundwater and where it is possible that contamination from the site may impact on the sewerage system.

2.7 The elements of the environment to be considered

The quality of the land and groundwater has the potential to affect the following elements of the environment:

- air (including odour in both indoor and outdoor environments);
- land (including aesthetics); and
- groundwater and surface water.

These elements apply at the site (on which the gasworks activities had been undertaken) and also off-site where a potential exposure pathway exists.

2.8 Beneficial uses of the segment

A beneficial use is a use of the environment or any element or segment of the environment which is conducive to public benefit, welfare, safety, health or aesthetic enjoyment and which requires protection from the effects of waste discharges, emissions or deposits, or from the emission of noise.

The beneficial uses to be protected for particular segments of the environment are declared in State environment protection policies (SEPP). The SEPPs describe the beneficial uses that apply to a particular geographic region or class of water, and identify indicators to be employed in measuring environmental quality and objectives necessary to sustain designated beneficial uses.

In particular, the following SEPPs are relevant:

- State environment protection policy (Groundwaters of Victoria), 1997 (herein referred to as the 'Groundwater SEPP');
- State environment protection policy (Prevention and Management of Contaminated Land), 2002, varied 26 September 2013 (herein referred to as the 'Land SEPP);
- State environment protection policy (Waters of Victoria), 2003 (herein referred to as 'SEPP (WoV)').
- State environment protection policy (Waters of Victoria) Schedule F6. Waters of Port Phillip Bay, 1997 (herein referred to as 'WoV Schedule F6'); and
- State environment protection policy (Air Quality Management), 2001 (herein referred to as the 'Air SEPP').

Land and groundwater are the primary segments of interest; however, as they can impact air and surface water segments the audit considered all four segments.

[9] EES incorrectly depicted the site boundary as including the Alinta site in many of its figures. The correct audit boundary is shown in Figure 2.

The Interim Audit considered whether the beneficial uses were being impacted, and the likelihood of the beneficial uses being realised. This audit has carried out further assessment drawing on the additional soil and groundwater information collected subsequent to the Interim Audit.

2.8.1 Beneficial uses of the land segment

The Land SEPP identifies a number of land use categories and protected beneficial uses for each land use category. Those that were relevant for the site included:

- Sensitive land, such as residential for the area covered by the Southport Site; and
- Recreational and open space use of the land.

The beneficial uses applicable to these land use categories are summarised in Table 3.

Table 3 Protected beneficial uses of land

Beneficial Use	Sensitive Use (Other)[10]	Recreation/Open space
Maintenance of ecosystems		
Natural Ecosystems		
Modified Ecosystems	✓	✓
Highly Modified Ecosystems	✓	✓
Human health	✓	✓
Buildings & structures	✓	✓
Aesthetics	✓	✓
Production of Food, flora & fibre	✓	

2.8.2 Beneficial uses of the groundwater segment

The SEPP Groundwater classifies groundwater into a number of segments based on the total dissolved solids (TDS) concentration of the groundwater. The beneficial uses to be protected for each of the groundwater segments are defined in the Groundwater SEPP, and reproduced in Table 4 below. Based on the background salinity reported by Golder[11] and EES (EES 2013, EES 2014C), groundwater at the site was classified as Segment A1: the beneficial uses protected for this segment were considered when assessing the risk posed to groundwater. All protected beneficial uses of Segment A1, and the relevance of the use (i.e. whether use was existing or likely at and beyond the boundary of the site) were considered in undertaking the risk assessment. EES (in EES 2013 and EES 2014C) classified groundwater as Segment A2. However, the auditor considers that, based on the TDS concentrations observed by Golder and EES in April 2011 (up six off-site wells to the south east had a TDS less than 500 mg/L), classification as Segment A1 is appropriate. This does not affect the findings of the audit, as the only differences in beneficial uses to be protected between Segments A1 and A2 are “desirable” potable water (A1) and “acceptable” potable water (A2); the drinking water investigation levels are the same for Segments A1 and A2 (i.e. NHMRC, Australian Drinking Water Guidelines, 2011).

In addition to the beneficial uses defined in Table 4, consideration was also given to the potential for groundwater contamination to adversely affect human health and aesthetics through volatilisation of contaminants, and to adversely affect the operation of sewerage

[10] The Land SEPP separates Sensitive Land Use into “High Density” and “Other”. The Southport Community Nursing Home is considered to lie within “Other” as it is a more sensitive land use than high-density, defined as “a density greater than one dwelling per 200 m^3 or a residential building greater than 4 storeys” (EPA Environmental Auditor (Contaminated Land), Guidelines for Issue of Certificates and Statements of Environmental Audit, Publication 759.2, 2014).

[11] Further Groundwater Investigation, 29 November 2006

systems and receiving waters through leakage into subsurface sewerage and stormwater systems.

2.9 Relevant audit criteria

Table 4 Protected beneficial uses of groundwater

Beneficial Uses	Segments (mg/L TDS)				
	A1 (0-500)	A2 (501-1000)	B (1001-3500)	C (3501-13,000)	D (> 13,000)
Maintenance of ecosystems	✓	✓	✓	✓	✓
Potable water supply					
Desirable	✓				
Acceptable		✓			
Potable mineral water supply	✓	✓	✓		
Agriculture, parks & gardens	✓	✓	✓		
Stock watering	✓	✓	✓	✓	
Industrial water use	✓	✓	✓	✓	✓
Primary contact recreation (eg. Bathing, swimming)	✓	✓	✓	✓	
Buildings and structures	✓	✓	✓	✓	✓

2.10 Auditor support team

Members of the auditor's support team utilised for this audit included:

- Eric Friebel (contaminant transport, soil vapour, and assessment of exposure pathways and risk);
- Paul Bolger (hydrogeology); and
- Barry Mann (hydrogeology and remediation).

In addition, the auditor was assisted by other GHD personnel as required, including Kate McCallum and Penny Flukes.

2.11 The approach taken for the audit

2.11.1 Background

The approach taken for the audit was developed from the findings of the Interim Audit. The approach outlined in the draft audit scope (Appendix B) broadly included:

- First stage:
  - The identification of data gaps, and associated sampling and analysis to address the gaps;
  - An assessment of whether the site could continue to be managed in a responsible manner until the additional works were designed and revised management plans (i.e. CMPs, revisions of ICMPs) were implemented; and

  - Whether proposed remediation works and plans for ongoing management of the site (i.e. CMPs) prepared by the consultant were consistent with reducing the risk to beneficial uses to an acceptable level.

- Second stage:

  At the time of preparation of the draft scope, it was envisaged that the second stage would consider the condition of the site after the remediation works and improvements in management had been implemented, giving consideration to:

  - Where the risk of any possible harm of detriment to a segment or an element of the environment was determined, recommendations for the measures necessary to reduce the risk to an acceptable level;
  - Where the risk of any possible harm or detriment to a segment or an element of the environment could not be determined, the measures necessary to ensure that risk to a segment would be able to be determined in the future;
  - Monitoring or modelling of data as deemed necessary;
  - Improvement of environmental performance, management systems and monitoring programs as necessary; and
  - Discussion with stakeholders regarding achievable timeframes for implementation of any recommendations that were expected to be made based on the findings of the audit.

The second stage of the audit was expected to take some time to complete, as the plans for the site's redevelopment were not finalised at the time of the draft scope.

This audit has completed the first stage outlined above (i.e. prior to remediation works having been carried out); the need for a further audit stage is discussed in Section 6.

2.11.2 Final approach adopted

Once the further investigation works into groundwater contamination (on and offsite), potential soil vapour emissions into buildings, and the extent and quality of site capping were undertaken, the approach to the audit was further refined. The assessment findings are discussed in detail in Sections 4.3 and 4.4, summarised briefly as follows:

- **Soil vapour:** Results from two ambient air sampling events undertaken in buildings at the site (completed in summer and winter) indicated that volatiles resulting from gasworks contamination were not at concentrations that would pose a risk to persons using the buildings. Elevated concentrations were detected at some locations, but were found to be related to the use of chemicals in the various artist's workshops and studios.
- **Groundwater:** A total of 43 monitoring wells were installed at and surrounding the site to assess groundwater (35 wells installed by Golder, eight wells installed by EES). Wells were installed within the Brighton Group Aquifer, with the majority of wells screened to intersect the water table. Three deeper wells were screened at the base of the Brighton Group Aquifer. The groundwater assessment indicated that the water table was being drawn down several metres below its natural level (and below sea level) by the sewers surrounding the site. Groundwater monitoring indicated that groundwater at the site was impacted by a range of gasworks-related contaminants. There was no evidence of Non-Aqueous Phase Liquid (NAPL) such as liquid tar in groundwater. All beneficial uses of groundwater were precluded by contamination beneath the site, however it was considered that none of the beneficial uses were likely to be realised (given the site is, and will continue to be managed by CoPP under two CMPs, one for the Park and one for the Southport site).

The investigation concluded that groundwater migrating from the site was captured by the sewers, with most of the contaminated groundwater migrating directly to the sewers without passing beneath neighbouring properties. An exception was a small area to the northeast of Richardson Street where groundwater impacted primarily with ammonia and TDS was migrating beneath residential properties before reaching the South Yarra Sewer Main beneath Bridport Street. Concentrations of TDS, ammonia, total cyanide, several metals, benzene, naphthalene, TRH C_6-C_9 and C_{10}-C_{36} were above the investigation levels for one or more of the beneficial uses maintenance of ecosystems, drinking water, recreational use and irrigation. It was considered possible that in this area residents might extract groundwater for recreational use (e.g. to fill swimming pools), and garden watering, and that the groundwater may not be of suitable quality for these uses.

- **Site capping:** 41 locations were investigated across the site to assess the integrity of a 0.5 m cap that had historically been placed over the site. It was found that the nature and composition of the surface soils varied considerably, and 'gasworks waste' was present in the top 0.5 m of soil with PAHs, cyanide, TRH[12] and various metals contamination above the relevant health investigation levels. Viscous tar was identified at three locations (approximately 0.3 m to 2.7 mbgl), and solid tar at another three locations.

  EES undertook a comparison of results with the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPM 1999), and the auditor has also compared the analytical data for surface soils against the HILs and EILs specified in the *National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1)* (NEPM 2013). The comparison of analytical data against the HILs and EILs listed in the NEPM 2013 showed that concentrations of total PAHs, benzo(a)pyrene (as the toxicity equivalent quotient (TEQ)), total cyanide and naphthalene exceeded the NEPM A and C HILs at some 27 locations across the site. The majority of concentrations were below the NEPM 2013 EIL criteria, with the exception of a single result for naphthalene in a sample at a depth greater than 0.5 mbgl, and isolated results for arsenic, copper, lead and zinc. The majority of BaP concentrations were above the NEPM 2013 ESL (0.7 mg/kg) for fine soils in an urban residential and public open space land use setting.

  The contamination was found both in soils containing visible evidence of gasworks waste and in a few instances where there was no visual evidence. This suggested the contamination comprised randomly distributed heterogeneous particulate material, rather than comprising homogeneous areas or "hotspots" of significant extent (though such areas might also exist). It was concluded that it would not be possible to reliably and simply (e.g. visually) distinguish areas where the existing capping layer did not contain contamination at levels in excess of the criteria.

Based on the findings, EES concluded that, rather than expending further funds and effort on attempting to areas that would comply with the requirements for an effective capping system, it would be more reliable to simply assume that shallow soils (i.e. less than 0.5 m depth) are contaminated, and to plan for remediation accordingly. The auditor agrees with this finding and approach.

EES undertook an evaluation of several possible remedial options to reduce the risk associated with soil contamination to an acceptable level; these options are outlined in Section 5.4 of the RAP (EES 2014B). EES concluded that a cap and contain approach was the most practicable

[12] Total Recoverable Hydrocarbons (TRH) and Total Petroleum Hydrocarbons (TPH) are used by different laboratories to describe the same analytes. EES has referred to both TRH and TPH. Therefore, for consistency throughout this report, Total Recoverable Hydrocarbons (TRH) has been used to describe fractions C_6-C_9 and C_9-C_{36} (as per NEPM 1999), and fractions C_6-C_{10} and >C_{10}-C_{36} (as per amended NEPM 2013).

strategy, and that the remedial work could be integrated with the preparation of a landscape plan that was being considered by CoPP for the long term development of the park. In finalising the RAP, EES worked with CoPP's landscape architects to define the components of the landscape plan that would meet the requirements for capping layer. Taking this approach would allow the audit to be completed and a conclusion reached as to whether the proposed remedial strategy was appropriate and would meet the requirements of the various stakeholders, before undertaking the remediation work.

Assuming that there is stakeholder agreement with the proposed strategy, the remedial works can then take place, with subsequent verification by and auditor that the proposed remedial works and auditor's recommendations have been completed satisfactorily.

In light of this, the approach to the audit was revised to involve the following:

- Determine the risk to beneficial uses of the land with respect to the existing and proposed future land use;
- Determine the risk to on-site and off-site beneficial uses of groundwater with respect to existing and proposed future land use;
- Evaluate whether the proposed remedial and management actions are sufficient to reduce the risks to an acceptable level; and
- Review the CMPs prepared by EES (to replace the existing ICMPs) for the Gasworks Park and the Southport site in light of the above conclusions.

The evolving approach and proposed remediation strategy was discussed with EPA on several occasions, as noted in Section 2.3.

2.11.3 Audit tasks

The following key tasks were undertaken (not necessarily in order of completion) to assess the risk of harm in the context of the ongoing use of the site. These are discussed in Sections 4 to 6.

- Review of further soil, soil vapour and groundwater data that was collected by EES subsequent to completion of the Interim Audit;
- Site visits by the auditor and his representatives to inspect investigation works and site conditions;
- Review of the Interim Audit risk assessment in light of new data to re-evaluate potential risks to onsite and offsite users and beneficial uses from residual soil and groundwater pollution;
- Review of the RAP prepared by EES to address risks associated with soil and groundwater contamination, and provision of recommendations;
- Review of the CMPs for the Gasworks Park and Southport site;
- Several meetings and discussions with EPA during the course of the audit, to update and seek agreement on the approach. The key outcomes of these meetings are documented throughout this report; and
- Based on the available data and findings of the risk assessment, provision of recommendations for further assessment, remediation and/or monitoring requirements as may be necessary to reduce the risks to human health and the environment (on and offsite) to an acceptable level.

2.12 Period of time over which the audit was conducted

As the audit was initiated by CoPP on a voluntary basis, there was no statutory deadline for completion and delivery of the audit report. The interim audit was undertaken between June 2007 and July 2008. The second stage of the audit (this audit report) commenced in August 2010 at the request of CoPP. Completion of the second part of the audit was reliant on completion of a plan for remedial works (i.e. the RAP) and a future management strategy that would be acceptable to stakeholders.

2.13 Considerations and exclusions in the development of the scope for the audit

The audit assessed the risk to the existing and longer-term land uses at the site and the surrounding environment beyond the site boundary posed by the activities associated with the former gasworks and the resulting contamination at the site, and how the risks may be reduced to an acceptable level.

The audit has considered the soil and groundwater information available at the time of reporting.

The audit has not considered activities conducted at nearby premises (e.g. operations at the Alinta site). The audit does not provide a statement as to the suitability of the land for its current or intended use, or contain a *Clean Up to the Extent Practicable* (CUTEP) submission.

2.14 Use of risk assessment

The significance of the risks were assessed using a semi-quantitative methodology based on AS/NZS ISO 31000:2009 *Risk Management – Principles and guidelines* and IEC/ISO 31010 *Risk management – Risk assessment techniques.* Any requirements and recommendations for improvement focused on the higher risks.

Descriptors for the assignment of “likelihood” (of a hazardous event occurring), “consequence” (the impact if the hazardous event occurs) and a matrix for assigning “risk” in terms of the likelihood and consequence adopted in the Interim Audit report were reviewed, and minor modifications were made to the descriptors to better differentiate between soil and groundwater contamination. No changes were made to the risk matrix. The descriptors and risk matrix are provided in Appendix C. The risk matrix provides descriptors for severity that include consideration of the magnitude of concentrations of contaminants with respect to the guidelines. With respect to groundwater, these scales are relevant to guidelines that are health based (e.g. benzene), but do not apply to guidelines that are aesthetic based (e.g. ammonia). This has been taken into account when assigning the severity (or “consequence”) of impacts arising from soil and groundwater contamination.

The assessment of risk involved a detailed review of the information from investigations undertaken by EES after the Interim Audit, and a re-evaluation of the likelihood and consequence, and hence risk associated with impacts arising from the soil and groundwater contamination. This evaluation included consideration of:

- The impact that might result if there were no controls (this assists in establishing the importance of the controls); and
- The effectiveness of existing or proposed management controls and/or remedial actions, and whether additional measures might be required.

This process provided an understanding of the importance of a control, the effectiveness of control, where improvement was required, and information gaps.

2.15 Level of stakeholder involvement in the environmental audit

The audit involved:

- Ongoing liaison with CoPP and the assessment consultant, EES;
- Discussions with CoPP's landscape architect regarding the requirements for capping the site; and
- Discussions with EPA and the Department of Treasury and Finance (DTF) on the findings of the audit at key stages and to confirm that the strategy being adopted was consistent with their requirements.

2.16 Environmental audit report

This audit report provides an updated assessment of the risk of any possible harm or detriment to a segment or element of the environment, based on additional soil and groundwater assessment information. The report includes:

- An assessment of proposed remedial works and management strategies to determine whether they will be effective in reducing the risk of possible harm or detriment to a segment or an element of the environment to an acceptable level;
- Where the risk is determined to be unacceptable, recommendations for additional measures including further investigations and/or remedial and management strategies and a timeline for implementation, that are necessary to reduce risk to acceptable levels; and
- Where the risk of any possible harm or detriment to a segment or an element of the environment could not be determined, the measures necessary to allow the risk to be determined.

3. Beneficial uses requiring protection

3.1 Introduction

As described in Section 2.8, the existing and potential beneficial uses of the land, groundwater, air and potentially surface water segment(s) of the environment need to be identified before any risk of possible harm or detriment to them can be assessed. While land and groundwater are the primary segments of interest, contamination of these segments can impact air and surface water segments, and therefore the audit considers all four segments.

The beneficial uses to be protected for particular segments of the environment are declared in the relevant SEPPs: the beneficial uses of each of these segments were provided in Section 2.8.

A site-specific assessment of the beneficial uses and the relevant receptors of impact to these beneficial uses have been provided in the following sections. Consideration has been given to the various pathways and receptors that can be impacted. In this analysis, consideration was given to those beneficial uses that were relevant and existing, and those that were only "potential" and were unlikely to be realised. This distinction was made by using filled and unfilled circles in the various tables. It was expected that those that were indicated as only having "potential" to be realised had a lower probability of effect in the risk assessment.

3.2 Beneficial uses of the land segment

The Land SEPP refers to the *National Environment Protection (Assessment of Site Contamination) Measure December 1999* (referred to in this report as NEPM 1999), which was formulated by the National Environment Protection Council (NEPC), under the *National Environment Protection Council Act 1994.* All the States and Territories of Australia were signatories to the making of the NEPM, including Victoria under the *National Environment Protection Council (Victoria) Act 1995.* NEPM 1999 was amended in May 2013 (referred to in this report as NEPM 2013).

All of the soil assessment work for the audit was undertaken in 2011 which was before the NEPM 2013 was released. The EPA advised that a 12 month transition process from May 2013 applies to the implementation of the NEPM 2013, and, as such, the auditor considers that use of NEPM 1999 was appropriate for the site capping investigation. However, for all further works and assessment of the site, the auditor considers the NEPM 2013 should be adopted. EES has adopted the NEPM 2013 in the RAP. The auditor considers this an appropriate approach, given the RAP specifies requirements for soil quality at the site post-remediation, and is a working document that is to be implemented in the future.

The Land SEPP identifies the protected beneficial uses for each land use category. The categories relevant to the site include:

- Sensitive use: consisting of land used for residential purposes, such as the aged-care facility at the Southport site;
- Recreational and open space use: consisting of general open space and public recreation areas, relevant to Gasworks Park; and
- Commercial: consisting of a range of commercial and business activities. There were 11 buildings on the site used for arts-related activities (i.e. sculpture, ceramics, a bookshop, and a theatre) as well as buildings on the Southport Site. Maintenance and other park workers are included in this category.

The scope of the audit also considered the impact that may be posed beyond the site boundary by the site. The offsite land use categories that have been identified include:

- Sensitive use: residential land;
- Recreational and open space uses;
- Commercial uses; and
- Industrial uses (e.g. Alinta, adjacent to the north of the site).

The beneficial uses applicable to these land use categories are summarised in Table 5 and Table 6.

With respect to the beneficial use "human health", the receptors that were considered include:

- Park users – adults and children;
- Workers – surface (e.g. within buildings and maintenance workers/gardeners) and subsurface workers; and
- Residents – Southport site and offsite residential.

Table 5 On-site – beneficial uses of land

Land Use / Beneficial Use		Sensitive Use (Other)	Recreation and Open Space	Commercial
Maintenance of Ecosystems	Natural			
	Modified	●	●	●
	Highly Modified	●	●	●
Human Health		●	●	●
Buildings & Structures		●	●	●
Aesthetics		●	●	●
Production of Food Flora and Fibre		●		

NOTES:

Empty cell Land SEPP does not require the beneficial use to be protected

○ Land SEPP nominates the beneficial use to be protected – the beneficial use is not likely to be realised

● Land SEPP nominates the beneficial use to be protected – the use is either existing or likely to be realised, i.e. potential use

Table 6 Off-site – beneficial uses of land

Land Use / Beneficial Use		Sensitive Use (Other)	Recreation and Open Space	Commercial	Industrial
Maintenance of Ecosystems	Natural				
	Modified	●	●		
	Highly Modified	●	●	●	●
Human Health		●	●	●	●
Buildings & Structures		●	●	●	●
Aesthetics		●	●	●	●
Production of Food Flora and Fibre		●	●		

NOTES:

Empty cell Land SEPP does not require the beneficial use to be protected

○ Land SEPP nominates the beneficial use to be protected – the beneficial use is not likely to be realised

● Land SEPP nominates the beneficial use to be protected – the use is either existing or likely to be realised, i.e. potential use

3.3 Beneficial uses of the air segment

The Air SEPP identifies the beneficial uses of the air segment, and these will be considered with respect to whether the subsurface contamination at the site poses a risk to recreational users of the Gasworks Park and residents/workers at the Southport site.

The air issues under consideration in the screening risk assessment included:

- Odorous pollutants (e.g. if intrusive remediation were to be undertaken which resulted in odours being released into the local atmosphere); and
- Volatile chemicals (carcinogens and non-carcinogens) might pose a vapour risk to on-site users and nearby sites, as a result of residual contamination at depth.

The impact of these issues on human health and aesthetic enjoyment has been considered within the broader context land-based uses of the site and offsite.

3.4 Beneficial uses of groundwater

The Groundwater SEPP classifies groundwater into a number of segments based on the TDS concentration of the groundwater. The beneficial uses to be protected for each of the segments of groundwater are defined in the Groundwater SEPP, and are reproduced as Table 7.

The relevant groundwater segment for the Gasworks Site is understood to be Segment A1 based on background salinity (EES 2013 and EES 2014C), and the beneficial uses protected for this segment have been considered when assessing the risk posed to groundwater.

All protected beneficial uses of Segment A1, and the relevance of the use (i.e. whether the use is existing or likely at and beyond the boundary of the site) have been considered in undertaking the screening assessment.

Table 7 presents a summary of the beneficial uses of groundwater that are identified for:

- Onsite - Gasworks Park and the Southport Site;

- Offsite – near to the site (i.e. the area just beyond the boundary of the site); and
- Offsite – far from the site (e.g. Western Treatment Plant and Port Phillip Bay, both potential receivers of groundwater emitting from the site).

Groundwater from the site has been found to discharge to sewers surrounding the site (EES 2013 and EES 2014C). Under the terms of the SEPPs, these sewers do not pose a beneficial use that is to be protected. However, for the purposes of this audit, the potential for contaminated groundwater to enter the sewers and to affect the use of the sewers and sewerage system was included within the audit risk assessment, as this is important for ongoing management of groundwater contamination.

In assessing impact on the sewerage system, consideration was given to the overall contaminant load expected to be received by the sewer, and its significance in the context of the overall sewer capacity.

Table 7 Beneficial uses of groundwater onsite and immediate surrounds

Beneficial Use		On-site	Off-site (near site)	Off-site (far from site)
Maintenance of ecosystems		○	○(1)	●
Potable water supply	Desirable	○	●	●
	Acceptable	○	●	●
Potable mineral water supply		Note a mineral water zone	Not a mineral water zone	Not a mineral water zone
Agriculture, parks and gardens		○	●	●
Stock watering		○	●	●
Industrial water use		○	●	●
Primary contact recreation		○	●	●
Buildings and structures		○	●	●

NOTES:
(1) No nearby water courses were identified.
(2) Waters of Port Phillip Bay (see Section 3.5)
Empty cell: Land SEPP does not require the beneficial use to be protected

○ Land SEPP nominates the beneficial use to be protected – the beneficial use is not likely to be realised

● Land SEPP nominates the beneficial use to be protected – the use is either existing or likely to be realised, i.e. potential use

3.5 Beneficial uses of surface water

The Groundwater SEPP prescribes that the beneficial use *maintenance of ecosystems* must be protected, and that groundwater shall not cause receiving waters to be affected to the extent that the level of any water quality indicator specified in the relevant SEPP for surface waters is exceeded. The groundwater investigations undertaken subsequent to the Interim Audit indicated that groundwater does not discharge to Port Phillip Bay (refer Section 4.3.2 for further discussion which notes that the level of groundwater at the site is below the level of waters of Port Phillip Bay), however, for completeness and consistency Port Phillip Bay has been retained in the screening risk assessment, although beneficial uses have been identified as unlikely to be realised (summarised in Table 8).

As noted in Section 3.5, Port Phillip Bay is covered by a variation to the SEPP (WoV). The aquatic ecosystems that are to be protected lie within the “general” segment of WoV Schedule F6. Similar to the Groundwater SEPP, all protected beneficial uses of the WoV Schedule F6 “general” segment, and the relevance of the use (i.e. whether the user is existing or likely, and whether a contamination pathway exists) are considered below.

Table 8 Beneficial uses of the general segment of Port Phillip Bay

Beneficial Uses		General Segment
Maintenance of aquatic ecosystems and associated wildlife	Natural ecosystems	
	Substantially natural ecosystems with some modification	○ (1)
	Highly modified ecosystems with some habitat values	
Water based recreation	Primary contact (e.g. swimming, water skiing)	○
	Secondary contact (e.g. boating, fishing)	○
	Aesthetics enjoyment (e.g. walking by the water)	○
Production of molluscs for human consumption	Natural populations (e.g. the consumption of natural molluscs)	○
	Aquaculture (e.g. the consumption of molluscs from declared aquaculture zones included in a shellfish sanitation program by the Responsible Authority)	○
Commercial and recreational use of edible fish and crustacean		○
Navigation and shipping		○
Industrial water use		○

NOTES:
(1) 90% level of protection to be applied (ANZECC/ARMCANZ 2000)

Empty cell: WoV Schedule F6 does not require the beneficial use to be protected
○ WoV Schedule F6 nominates the beneficial use to be protected – the beneficial use is not likely to be realised
● WoV Schedule F6 nominates the beneficial use to be protected – the use is either existing or likely to be realised (i.e. potential use).

4. Information reviewed

4.1 Documents reviewed

Key documents that were reviewed as part of the current audit are listed in Table 9. Work plans prepared by EES were also reviewed for all phases of assessment work (details are provided in Section 1 and Appendix J).

Table 9 Documents reviewed

Author	Document Date	Document Title	Reference throughout this report	Location in this report
GHD	December 2008	*Section 53V Environmental Audit – Interim Report, Gasworks Site, Albert Park*	GHD 2008	Appendix A
EES	November 2012	*Indoor Ambient Air Vapour Investigation at Former South Melbourne Gasworks, Version 2*	EES 2012	Appendix D
EES	September 2013	*April 2011 Groundwater Investigations at Former South Melbourne Gasworks, Version 3*	EES 2013	Appendix E
EES	March 2014	*Site Capping Investigation at Former South Melbourne Gasworks, Version 3*	EES 2014A	Appendix F
EES	March 2014	*Remediation Action Plan for the Former South Melbourne Gasworks, Albert Park, Victoria, Version 4 (ref. 210074_v4)*	EES 2014B	Appendix G
EES	April 2014	*Supplementary Groundwater Investigation at Former South Melbourne Gasworks, Version 3*	EES 2014C	Appendix H
EES	July 2014	*Contaminant Management Plan for the Former South Melbourne Gasworks Site, Albert Park, Victoria, Version 2*	EES 2014D	Appendix I
EES	July 2014	*Contaminant Management Plan for the Southport Nursing Home, Albert Park, Victoria, Version 1*	EES 2014E	Appendix I
CoPP	Received 18 June 2014	*Gasworks Arts Park – Soil remediation decision making process including considerations for tree protection*	CoPP 2014	Appendix M

4.2 Summary of Golder reports

A summary of Golder reports made available to the auditor was provided in the Interim Audit Report (GHD 2008). EES provided a detailed summary of Golder's findings in its initial sampling and analysis plan[13] (EES 2010). Key findings from Golder's investigations were:

- A site history review identified the potential for soil and groundwater contamination from historical on-site gasworks processes. Minimal soil remediation appeared to have been completed, apart from a small area (reportedly to 0.5 m depth) in the south eastern corner where contaminated material was excavated and replaced with 'clean soil'. Further soil assessment was later undertaken at the Southport site, with Golder concluding the area was not suitable for redevelopment as medium/high density residential, recreational open space, or aged care unless remediated or appropriately managed due to concentrations of CoPC (lead, BaP, total PAH, TRH >C_9, benzene and total CN) and aesthetic issues.
- The site was declared suitable for use as a park by EPA Victoria in 1992;

[13] *Sampling and Analysis Plan for the Former South Melbourne Gasworks, Albert Park, Victoria, Version 1,* October 2010 (EES 2010)

- A limited assessment of surface soils found concentrations of total PAHs and BaP above the applicable NEPM HIL guidelines. Visual signs of contamination were identified, including the presence of coke and spent oxides in some garden beds and the playground, and odorous soil stockpiled on site from recent excavation works.
- A limited vapour assessment was completed. Indoor soil samples collected from four buildings contained concentrations of phenol, ethylbenzene, toluene and xylene, though no unacceptable risk to occupants or residents was identified. Samples from four soil gas bores situated outdoors identified multiple CoPC, but it was concluded there was no risk to recreational users of, or works at the park. It was also concluded that the risk to site users associated with consumption of edible vegetables was low.
- Golder developed two ICMPs for ongoing management of contaminated soils at the site (Gasworks Park and Southport site), with an objective of minimising the risk of exposure of site users to contaminated soil. It was anticipated the ICMPs would be updated after one to two years.
- Golder developed a hydrogeological conceptual for the Gasworks precinct, and concluded that the South Yarra (Bridport Street) and Hobsons Bay (Pickles Street) sewers were significantly drawing down groundwater in the area of the site, and hence groundwater from the site was primarily being captured by the sewer network, with the exception of an area to the north east. This was supported by standing water levels (SWLs) obtained across several monitoring events.
- Several groundwater assessments found that groundwater at the site was contaminated with common gasworks contaminants (metals, ammonia, cyanide, sulphate, TDS, PAHs and MAH). Ammonia was identified as the main contaminant of concern. The contribution of contaminated water to the sewer was not considered to represent an unacceptable risk to the Werribee Treatment Plant environment. Further investigation of groundwater offsite to the north east was recommended, particularly with respect to ammonia.
- The Pickles Street sewer was found to be leaking in the vicinity of Richardson Street (GW34, based on SWLs in deeper groundwater wells).

4.3 Summary of EES assessment reports

This section provides a summary of EES' investigations into indoor air quality (vapour intrusions), the extent and quality of existing site capping, and groundwater (onsite and surrounding the site). The RAP prepared by EES following completion of the assessment works has been discussed in Section 5.4.

4.3.1 Indoor air quality assessment (EES 2012)

EES undertook an assessment of ambient indoor air quality in buildings located at the site (Gasworks Park and the Southport site) to assess the potential for vapour intrusion into buildings from buried gasworks waste and/or residual contamination (EES 2012). Works undertaken included:

- Two rounds of sampling conducted, the first in July 2011 (Round 1: 17 to 19 July 2011) and the second in January/February 2012 (Round 2: 29 January to 1 February 2012). The two rounds of sampling were completed in summer and winter to account for seasonal variability.
- Prior to sampling, site inspections were conducted to assess building design and identify potential cross contaminating sources within the buildings. The auditor and auditor's assistant attended the final inspection on 6 June 2011 to view the proposed sampling locations.

- Samples were collected from a total of 13 sample locations during each round (refer Figure 3), using passive summa canisters over an eight hour (Gasworks Park) or 24 hour period (Southport site). A mobile weather station was used during sampling to measure site specific meteorological conditions.
- Samples were analysed by ALS (a NATA accredited laboratory) for 84 volatile organic compounds (VOCs) in air.

Key findings included:

- Detectable concentrations of vapours were typically low.
- Concentrations of benzene, naphthalene and trimethylbenzene at three separate locations exceeded initial screening criteria (which were described in Sections 10.1.1 and 10.1.2 of EES 2012). When screening criteria were modified to account for a limited exposure duration during the day (criteria were divided by a factor of four to account for an assumed exposure time of 40 hours per week), only benzene concentrations in the Gasworks Park sculpture studio from both rounds of sampling exceeded the adjusted criteria.
- EES considered the observed concentrations of volatile contaminants, including benzene, were attributed to indoor sources (e.g. artist's supplies) or background levels rather than a result of gasworks waste at the site. A discussion was provided in Section 13.4 of EES 2013. EES concluded that subsurface vapour intrusion appeared to be negligible and unlikely to pose an unacceptable risk to building users. No remedial works were considered necessary.

Auditor's comments on indoor air vapour assessment

The indoor air assessment is adequate to assess whether vapours arising from soil and/or groundwater contamination at the site are resulting in unacceptable concentrations of contaminants of concern in buildings at the site. The sampling methodology and analytical schedule adopted by EES were appropriate.

The results indicate that users and residents of existing buildings at the site are unlikely to be exposed to unacceptable concentrations of contaminants arising from soil and/or groundwater contamination at the site. This is only applicable to buildings in their current state; should new buildings be constructed the risk associated with vapours would need to be reassessed.

4.3.2 Groundwater

April 2011 Groundwater Assessment (EES 2013)

In April 2011 EES undertook an assessment of groundwater beneath and proximate to the site. The objective of the investigation was to gain an understanding of groundwater quality (with respect to contamination originating from the site) and hydrogeological properties of the shallow (i.e. Brighton Group) aquifer beneath and surrounding the site.

The following scope of works was undertaken:

- Drilling and installation of five shallow wells screened across the water table within the Brighton Group Aquifer (GW39, GW40 and GW41 onsite, GW37 and GW38 offsite) and three deeper wells (to the base of the Brighton Group aquifer, GW42D to GW44D onsite)) groundwater wells.
- Development of all newly installed and existing groundwater wells using airlifting (deep wells), pumping, bailing and/or surging.

- Gauging of 31 existing and eight new wells (total of 39 wells) to measure the standing water level (SWL).
- Collection of groundwater samples from 39 wells, using low flow methodology for the majority of wells (a bailer was used to purge and sample GW4 due to low recharge resulting in excessive drawdown). Samples were analysed by ALS for a range of CoPC.
- Slug tests (rising and falling head) were conducted on six groundwater wells (shallow wells GW7, GW37, GW30 and GW40, and deep wells GW42D and GW44D) to provide an estimate of aquifer properties.

Key findings included:

- Groundwater flow and discharge to sewers:
  - Groundwater levels beneath, and in the immediate vicinity of the site and sewers were below sea level (i.e. less than 0 mAHD). Consistent with Golder's findings, EES inferred a constant drawdown and gradient towards the South Yarra and Hobson's Bay sewer, and to a lesser extent the Pickles Street sewer, indicating continuous groundwater seepage along the sewer length. The Richardson Street sewer was found to be approximately 1 m above the water table, and hence would act as a source to groundwater rather than a sink (if leaking).
  - EES concluded that groundwater flow at and in the vicinity of the site is being controlled by the deep sewers surrounding the site to the west (Pickles Street sewer), south west (Hobsons Bay sewer) and south east (South Yarra sewer), with all groundwater from the site ultimately being captured by these sewers. Groundwater flow direction across the site was variable, but predominantly radially outwards from the site towards the sewers (see Figure 6).
  - EES inferred the groundwater flow on the northern section of the site (proximate to the Alinta site) was to the south west in the 2011 assessment, but to the north east in the 2013 assessment. The auditor considers these differences in flow direction are most likely to be result of differing interpretations of the potentiometric contouring, rather than the result of differences in groundwater flow. The auditor understands that groundwater is flowing to the west and southwest in this area, with the Pickles Street sewer showing some influence on groundwater flow, particularly towards the northern portion of the site. However, the hydraulic gradient in this area is very flat and migration of PAH contamination identified in wells GW40 and GW41 (proximate to the Alinta boundary) is likely to be slow, irrespective of the source.
  - The hydraulic gradient across the site was estimated to range from 0.006 to 0.01, becoming steeper (greater than 0.01) towards the sewers on Bridport, Graham and Pickles Streets.
  - The average linear groundwater velocity in the Brighton Group was calculated to be approximately 5 m/year.
  - EES estimated the total discharge to sewers from the site was 11 m^3/day (4 ML/year). This was higher than Golder's estimate of 2300 L/day (2.3 m^3/day, excluding Pickles Street). The calculated flux was still found to be orders of magnitude lower than the expected typical daily flow in the sewer (EES 2013, Section 10.2). There was not deemed to be any unacceptable risk to workers at the Werribee Treatment Plan to which all sewerage discharges.
  - EES noted that should the sewers be repaired in the future, the contamination originating from the site was unlikely to impact the beneficial use of maintenance of ecosystems, as the closest receiving water body is Port Phillip Bay (the Bay), approximately 350 m south of the site. EES determined that under this scenario, the

hydraulic gradient towards the Bay would be so low that groundwater from the site would take thousands of years to reach the Bay, by which time the concentrations of contaminants originating from the site would be negligible. The auditor agrees that should the sewers be repaired in the future, even if preferential groundwater flow pathways existed (such as utility corridors) between the site and the Bay, it would be unlikely that concentrations of contaminants migrating from the site would reach the Bay at levels of concern, due to dilution and attenuation factors.

- Groundwater geochemistry
  - Groundwater in the south east (SE)[14] wells, not influenced by groundwater from the site, typically had low TDS (156 to 548 mg/L) with higher TDS in north east (NE) and north west (NW) wells (1 540 to 3 770 mg/L and 1 190 to 3 480 mg/L respectively). TDS in shallow onsite (OS) wells was highly variable (662 to 6 450 mg/L), likely influenced by dissolved phase contaminants such as sulphate and ammonia. Deeper wells had a much higher TDS (8 860 to 23 400 mg/L), with a similar chemistry to seawater. The higher TDS in deeper wells is possibly due to gasworks contamination, or to ingress of seawater migrating up the sewers from Port Philip Bay, or both.
  - EES concluded that based on TDS measurements, in accordance with the SEPP (Groundwater), groundwater was classified as Segment A2.
  - Both OS and offsite (NW/NE/SE) wells contained a broad range of water types, varying depending on proximity to the sewer and contamination levels. The geochemical profile of deeper groundwater is similar to seawater (with the exception of elevated ammonia).
- Groundwater contamination and impact on beneficial uses
  - Groundwater at the site was found to be contaminated with common gasworks contaminants, with concentrations of TDS, metals (primarily arsenic, cobalt, copper, lead and zinc), ammonia, total and free cyanide, sulphate, PAH, TRH[15] and MAH above the applicable investigation levels for one or more beneficial uses of groundwater.
  - Groundwater containing elevated ammonia, sulphate, total cyanide, sulphate, benzene, ethylbenzene, TRH and naphthalene concentrations was found to extend offsite to the north east below residential properties. EES concluded the groundwater contamination was likely originating from the site (though groundwater flow in this area was variable), and was ultimately being captured by the South Yarra sewer. A summary of all results exceeding the applicable guidelines is provided in Section 9.2 of EES 2013, and in Section 4.4.1 below.
  - Wells to the north and north west of the site also contained concentrations of various inorganics (including total cyanide and ammonia), metals, benzene and TRH C_{10}-C_{36} above the applicable investigation levels. EES concluded the hydraulic gradient in this area was slight, with flow likely to be variable, and concluded that contamination may have originated from the site or from an offsite source. As noted above, the auditor concurs that flow in the northern portion of the site is likely to be variable, but is likely ultimately towards the west and north west towards the Pickles Street sewer. This would suggest the site may be contributing to the elevated concentrations of contaminants, but that offsite sources may also a factor.

[14] In its analysis, EES grouped wells according to location, including onsite (OS), north west (NW), north east (NE) and south east) SE). A summary of wells and location was provided in Table 4 of EES 2013.

[15] TRH speciation analysis undertaken on three samples indicated the presence of aromatic hydrocarbons only. This indicated the TRH detected in these wells consisted predominantly of BTEX and PAHs.

- The highest concentrations of TRH, PAH and BTEX were identified in deep well GW44D, screened at the base of the Brighton Group aquifer and in shallower well GW24. GW44D is located at the eastern-most extent of the site (described as south east by EES), and GW24 in the southern portion of the site, near the south eastern boundary (Foote Street).
- There was no evidence of NAPL in groundwater on or offsite.
- Elevated concentrations of dissolved metals were observed in deep well GW42D compared with the remaining wells, which EES deemed 'false positives' due to the presence of colloids. The auditor did not agree with EES' explanation, but did not consider the elevated results to impact on the outcome of the audit (refer to the Auditor's QAQC review, Appendix J, for further discussion).
- The OVB aquifer which underlies the Brighton Group Aquifer was not directly investigated. However, EES concluded that due to an upward hydraulic gradient from the OVB to the Brighton Group aquifer, contamination was not expected to extend below the Brighton Group.
- All beneficial uses of groundwater on site are precluded by concentrations of gasworks-related contaminants, however, EES determined that based on the current and proposed ongoing use of the site as a park, and absence of groundwater extraction, beneficial uses on site are currently not being realised, nor will they be realised in the future for as long as the site is used as a park and nursing home, and is controlled by CoPP.
- The beneficial uses of primary contact recreation (e.g. extracting groundwater to fill swimming pools), irrigation, stock watering and drinking water were considered precluded in a residential area extending beneath Richardson Street offsite to the northeast, primarily due to concentrations of ammonia. EES considered that although these beneficial uses were unlikely to be realised given the availability of reticulated water and low yield of the Brighton Group aquifer, the possibility of groundwater being extracted for these uses could not be discounted.

- EES made the following recommendations in relation to groundwater at the site:
  - A further GME should be undertaken (this was subsequently completed in June 2013, discussed below), and the mass flux of contaminants discharging to the sewers should be confirmed.
  - A review of management and/or remediation strategies for the area of groundwater contamination to the north east of the site should be undertaken. This was undertaken as part of the RAP (EES 2014G), discussed in Section 5.4.
  - A Groundwater Quality Restricted Use Zone (GQRUZ) should be considered to cover the area of the inferred lateral extent of the contaminated groundwater plume extending offsite to the north east (EES estimated this to be approximately 20 to 30 properties). The auditor notes that only EPA can determine whether a GQRUZ is required.

June 2013 Groundwater Assessment (EES 2014C)

EES undertook a second round of groundwater monitoring and sampling at the site approximately one year later, in June 2013. The scope of works included:

- Gauging of 35 wells (GW27 could not be located) to measure SWLs,
- Collection of samples from 35 wells using low flow sampling methodology for the majority of wells (bailers were used for six wells with poor recovery). Samples were submitted to ALS for analysis of CoPC.

Key findings included:

- Groundwater flow and hydrogeological properties
  - Groundwater flow directions were generally consistent with the April 2011 assessment across the majority of the site, with the exception of the northern portion. Groundwater in this section of the site and proximate to the intersection of Richardson and Pickles Streets was inferred to flow to the southwest from Richardson street, as opposed to north/north east which was inferred in the previous groundwater monitoring event. As noted above, the auditor considers this is due to differing interpretations of potentiometric surface, rather than an inherent difference in groundwater flow direction, and considers it likely that groundwater in the northern portion of the site is flowing towards the west, south west and north west towards the deep sewers.
  - The hydraulic gradient across much of the site was low (0.007 to 0.02), becoming steeper (greater than 0.01) towards the sewers on Bridport, Graham and Pickles Streets.
  - Ultimately EES considered the monitoring event confirmed that groundwater flow beneath and surrounding the site is being controlled by the sewers to the east, south, and southeast.
  - The average linear flow velocity of groundwater was estimated to be approximately 11 m/year, slightly above the previously calculated velocity (5 m/year).
  - The total discharge to sewers surrounding the site (Hobsons Bay, Pickles Street and South Yarra sewers) was estimated to be 19 m^3/day (3 ML/year), which was slightly lower than EES' previous calculation. This rate of ingress is very small in comparison with total sewer flows.
- Groundwater contamination:
  - Analytical results were generally consistent with the April 2011 sampling event. Concentrations of one or more of MAH, naphthalene, TPH, metals, chloride, ammonia, sulphate, total and free cyanide, TDS, nitrate and pH in groundwater on site were found to exceed the applicable guidelines for all protected beneficial uses onsite. Concentrations of contaminants were typically higher around the periphery of the site compared with the centre, potentially reflecting local preferential recharge in the central portion of the site, as well as radial groundwater flow patterns.
  - There was no evidence of NAPL in groundwater on or offsite.
  - Concentrations of previously elevated metals in GW42D had decreased in this sampling event, and were generally consistent with other groundwater monitoring wells. EES commented that overall a comparison between metals results in the April 2011 and July 2013 sampling events could not be made due to April 2011 samples being laboratory filtered, and the July 2013 samples being field filtered.
  - Silica gel clean-up was conducted on a number (not all) of samples containing elevated TRH C_{10}-C_{36}. Following silica-gel clean up, only four wells (three onsite and one offsite) contained concentrations above the adopted criteria. EES concluded that approximate 16.5% to 100% of TRH compounds were attributed to natural organic influences rather than petroleum hydrocarbons.
  - Concentrations of various metals and inorganics (arsenic, boron, cobalt, copper, iron, lead, magnesium, manganese, nickel, selenium and zinc) were detected in groundwater on and offsite (predominantly NE and NW) wells above one or more investigation levels.

  - Ammonia, chloride, total cyanide, fluoride, TDS, nitrate, sulphate and pH were above (or below for pH) guidelines for one or more beneficial use in groundwater from on and offsite (predominantly NE and NW) wells.
  - Groundwater geochemistry parameters indicated a broad range of water types in the shallow wells, from Na-Cl dominated to Ca-SO_4 dominated. Deeper wells had a similar geochemical profile to seawater, with the exception of elevated ammonia.
  - EES concluded contamination to the immediate north east (ammonia, total cyanide, sulphate, TDS, various metals, TPH, benzene) and north west (ammonia, total cyanide, TDS, various metals, benzene (one well only)) of the site is likely attributed to the site, though it could also be due to the sewers and other non-specified sources. The auditor considers the contamination observed in groundwater in these areas is consistent with known gasworks contaminants, and considers former operations and residual contamination at the site to be the primary source of contamination.
  - EES concluded the dissolved phase contaminant plume was relatively stable, though with slight increases in various contaminant concentrations in some wells to the NW and NE. EES provided a breakdown of all inferred increases in Section 8 of EES 2014C.
- Impact to beneficial users of groundwater:
  - EES concluded that all beneficial uses of groundwater were precluded on site by concentrations of gasworks-related contaminants, however none of the beneficial uses were likely to be realised given the current and intended ongoing use of the site as a park, and absence of any onsite groundwater extraction bores.
  - EES determined the beneficial use of maintenance of ecosystems was not being realised at, or in the vicinity of the site as all groundwater was being captured by the surrounding sewer network.
  - The beneficial uses of potable water (acceptable), primary contact recreation, stockwatering and irrigation were precluded by groundwater contamination offsite to the north east, primarily through concentrations of ammonia and sulphate. Concentrations of benzene, TRH C_6-C_9 and TRH C_{10}-C_{36} were also identified above the investigation levels for two wells (GW37 and GW38). Although these beneficial uses were considered unlikely to be realised given the presence of a reticulated water supply and low yield of the Brighton Group, groundwater extraction was possible.
  - The concentrations of pH, sulphate, ammonia, arsenic, manganese, iron and benzene in groundwater exceeded the South East Water *Standards for trade waste discharge to the sewerage system*. However, EES noted these standards were intended for discharge of waste from land to sewer, rather than groundwater discharging direct to sewer.
  - It was concluded the lateral extent and concentrations within the plume were generally stable, with some increased in various contaminants noted in on and offsite wells. The auditor noted monitoring wells to the north east exhibited an increase in ammonia and cyanide concentrations. The auditor considered that further sampling events were required to establish whether these increases are representative of a trend or merely fluctuations.
- EES made the following recommendations in relation to groundwater:
  - Groundwater contamination at and surrounding the site should be managed in the future by a Groundwater Quality Management Plan (GQMP), as described in the RAP (EES 2014B);
  - A GQRUZ may be identified by EPA.

Auditor's comment on groundwater assessments

Overall the auditor considers the well network at and in the vicinity of the site provides a reasonable indication of groundwater quality beneath, and surrounding the site (up, cross and down gradient). Groundwater samples were analysed for an appropriate range of contaminants of concern, and sufficient sampling events were undertaken to allow a meaningful assessment of groundwater quality. However, ongoing monitoring of select wells within the network is required to establish contaminant concentration trends, and to monitor for any changes that may require action.

The auditor agrees with EES' conclusion that groundwater to the west, south west and south east is being captured by the surrounding deep sewers (Pickles Street, Hobsons Bay and South Yarra sewer mains). Based on the information provided it appears the Richardson Street sewer alignment is above the water table, and hence is more likely to act as a source of groundwater recharge rather than to be a receiver of groundwater.

The inference that contaminated groundwater that extends offsite beneath a minority of properties to the north east of the site (across Richardson Street) is ultimately captured by the South Yarra sewer main is reasonable. The lateral extent of this plume of ammonia-contaminated groundwater appears to be delineated. An important aspect that must be considered when assessing the risk associated with the offsite groundwater contamination, that EES did not provide comment on, is that ammonia appears to be the limiting contaminant within this area, concentrations of which preclude the beneficial use of primary contact recreation. The criterion for ammonia is based on aesthetics, rather than impacts to human health. This is an important distinction as it points to a reduced risk profile associated with extraction and use of contaminated groundwater (through reducing the severity of exposure). This is discussed further in Section 5.

The current flow pattern and hence containment of contaminants is dependent upon sewers surrounding the site capturing contaminated groundwater. Should sewers be repaired or altered, this could have a significant effect on the flow regime and hence risk to offsite receptors. Ongoing monitoring and consultation with the sewerage authority is required to identify significant changes that might result in an increased risk to offsite receptors. The auditor supports the implementation of a GQMP, including ongoing monitoring.

4.3.3 Site capping (EES 2014A)

EES undertook an investigation of soils at the site to establish whether a capping layer was present at the site, and gain a better understanding of the extent of contamination in shallow soils. Aside from a small area in the south eastern corner where up to 0.5 m[16] contaminated material was removed and replaced with "clean soil" (the quality of "clean soil" is not known), there has been no documented remediation of the site.

The scope of work undertaken was as follows:

- Soil samples were collected from 41 test pit and borehole (where access was restricted) locations across the site in January 2011. Sample locations were selected based on a grid, at a density of 13.1 points/ha[17].

[16] EES field investigations found clays extended to approximately 0.3 mbgl in this area, not 0.5 mbgl as reported.

[17] EES stated that some of the sampling points could "also be considered targeted as they were installed near or within the vicinity of the historical potential source of contamination". The auditor communicate to EES that sample locations can either be random (i.e. grid) or target, but not both. As the intent of the sampling was to provide a broad overview of soil conditions at the site, the incorrect use of terminology was not considered to impact the overall findings

- Sample locations were extended to a maximum depth of 3.0 mbgl (the maximum reach of the excavator). Samples were collected from the surface and at approximately 0.5 m intervals, or at changes in lithology or signs of contamination.
- A survey of the site topography was completed by qualified surveyors in February 2011, presented as Figure 6 in EES 2014A. The site survey illustrates the artificial mounding currently present across the site.
- Soil samples were screened in the field for volatile contaminants with a photo-ionisation detector (PID).
- Samples were submitted to ALS for analysis of CoPC. Leachability sampling (using Australian Standard Leaching Procedure (ASLP) for key CoPC was conducted on select samples.

Key findings included the following:

Soil profile

- The soil profile logged by EES was highly variable across the site, described in detail in Section 8.3 of EES 2014A. Broadly, the site stratigraphy comprises:
  - 0 - 0.4 mbgl: brown loam (majority of open areas of the site), or pathways consisting of sandy gravel/crushed rock (0.1-0.15 m thick);
  - 0.4 - 3.0+ mbgl: sand, gravel, silt and clay (reworked BGS and PMS) “heavily impacted with gasworks waste (free layers noted) including ash, coke, clinker, solid and viscous tar and spend oxides”. In the central portion of the site a layer of yellow/orange sandy clay was observed.
  - In the south east corner and an area proximate to the north east boundary a firm brown clay with “varying amounts of coke, ash and brick inclusions”.
  - Depth to natural soils (inferred to be Brighton Group sediments and Port Melbourne Sands) varying between 0.3 mbgl in the southwest corner to more than 3.0 mbgl at test pit TP7.
- Viscous tar was noted at three sampling locations (BH13 at 0.9 mbgl, TP26 at 0.3~2.0 mbgl, TP7 at 0.1-1.1 mbgl and 1.8-2.7mbgl)[18].
- Solid tar was encountered at four locations (TP7, BH11, TP6 and TP11). EES referred to this viscous tar observed in soil as NAPL.
- Spent oxides were observed at five locations (BH4, TP4, TP6, TP18 and TP20).
- Gasworks waste was visible in soils <0.5 m deep across the site, either mixed in with re-worked PMS and BGS, or as distinct layers. Gasworks waste was described as comprising “spent oxides, coke, ash, clinker, slag and solid to semi-viscous tar”, in some instances as a “separate distinct layer”.
- EES considered the brown loam and yellow/orange sandy clays was a capping layer at least 0.5 m thick (where present), however there was visible contamination throughout these soils, with gasworks waste observed at the majority of locations in soils <0.5 mbgl. EES noted the ‘capping layer’ only covered approximately half the site, with the remainder covered by building or gravel pathways, or brown clay (south eastern corner, to 0.3 mbgl). Figure 7 in EES 2014A showed several locations containing visible gasworks waste. The auditor notes that based on the borelogs, many more locations than shown on this figure contained visible gasworks waste at depths less than 0.5 mbgl.

[18] The auditor formally notified EPA of the presence of NAPL in soil on 28 February 2014. EPA provided a response on 12 March 2014.

Analytical results

- Laboratory analytical results indicated widespread contamination of soils across the site, with concentrations of metals (lead, arsenic, copper, mercury, nickel, zinc), total cyanide, sulfate/sulfide, cyanide, BaP, total PAH, naphthalene and TRH (>C_{10}-C_{40}) exceeding the applicable investigation levels for protection of human health and maintenance of ecosystems.
- EES derived site specific trigger levels (SSTL) for TRH based on a direct contact exposure pathway. Concentrations in many samples exceeded the SSTLs for TRH >C_{10}-C_{40}.
- PAH fingerprinting undertaken on samples that contained PAH concentrations above the investigation levels indicated a mixed source (ash, coke and/or tar) for the majority of samples, and spent oxides in two locations (BH4 and TP20). Tar was not always visible in those samples reporting a black coal tar signature. The distribution of tar was not strongly correlated with historical infrastructure. It was determined that bioavailability of PAHs could not be determined without doing specific bioavailability laboratory testing. Reference was made in Section 10.4 to bioavailability factors; the auditor does not consider there is sufficient evidence to adopt this approach (discussed further below). Furthermore, the auditor noted the PAH leachability tests were conducted well outside of holding time, potentially compromising results.
- EES concluded that based on the analysis of 11 samples for TRH speciation, it could be assumed that TRH in soil samples was predominantly aromatic. Silica gel clean up was not conducted on samples; therefore EES concluded that non-speciated results were subject to 'false positives'. The auditor does not consider this significant, as the contamination risk profile of samples containing high concentrations of TRH is determined by the more toxic constituents of the PAHs, rather than TRH.
- EES provided a detailed description of contamination associated with each soil type in Section 10.5 of EES 2014A, concluding that PAH concentrations above criteria appeared to be randomly distributed across the site rather than attributable to specific locations. Contamination was found both in samples containing visible signs of gasworks waste, and also in samples with no visible evidence of contamination.
- Elevated sulphur compounds were detected in eight samples of fill material. EES attributed this to spent oxides and/or naturally occurring iron sulphides (mainly pyrite) in the PMS or possibly imported Coode Island silt. EES concluded there was potential for some soils to generate acid if exposed to oxygen. The auditor noted that all samples with elevated concentrations of sulphur compounds were above the water table, and had historically been disturbed (i.e. not natural soils); therefore oxidation of sulfidic materials would have likely already occurred, as represented by the comparably low pH in some samples. The auditor does not consider that acid generation through oxidation of potential acid sulfate soils (PASS), if present at the site, is likely to pose a significant risk given the low likelihood of saturated soils being disturbed.
- With respect to sulfur compounds, EES recommended further sampling to assess "potential salinity and acid production potential of soils". The auditor did not consider this to be necessary given soils containing sulfidic material were likely to have already oxidized to at least some degree, and sulphur compounds did not directly pose a risk to human health or the environment. It can also be noted that the existence of gasworks wastes at depth is likely to be a more significant source of contamination than the PASS.
- EES concluded that underlying natural soils (where encountered) did not appear to have been significantly impacted by gasworks waste, with all samples analysed containing

concentrations of TRH and PAHs below the investigation levels. EES noted that as the focus of the investigation was to gain an understanding of shallow soil quality, vertical delineation of impacts was not undertaken at the majority of locations.

- Concentrations of other contaminants, including lead, total cyanide, sulfur compounds, TRH (>C_{16}-C_{34}) and naphthalene were found to be above the criteria for human health and/or ecosystems. However, EES did not consider these to be limiting contaminants, due to the following:
  - Statistical analysis indicated that the 95% UCL of all metals concentrations were below the human health criteria.
  - Although the 95% UCL for total cyanide was above the UCL, EES concluded it was not leachable. The auditor does not agree with the assumption that total cyanide is not leachable, as EES did not undertake leachability testing, and cyanide was detected widely in groundwater. However, the auditor does concur that cyanide is not a limiting contaminant due to its low volatility (cyanide is likely to be mainly present in complex form, such as the ferricyanide) and limited distribution. Furthermore, all samples that reported elevated total cyanide concentrations also contained PAH and BaP at concentrations above human health criteria. Therefore addressing the risk posed by the more toxic PAH components can be expected to address risks associated with cyanide.
  - Only concentrations of TRH C_{16}-C_{34} exceeded the 95% UCL. This fraction was predominantly comprised of PAHs, the limiting contaminants on site.
- EES provided a discussion on Tier 1 and Tier 2 criteria in Section 11.4.3, which indicated that Tier 2 criteria would be developed for specific contaminants. However, EES later concluded that a further Tier 2 risk assessment is not required given the proposed capping of the site. The auditor notes that while the discussion is confusing, an initial screening of soil analytical results against published criteria can be sufficient to allow a consideration of the risk posed to current site users by soil contamination, and to determine whether a control such as capping is required. The auditor undertook a review of the analytical data against appropriate criteria; this is discussed in Section 4.4.

Exposure pathway analysis:

- When considering the potential exposure of site users and occupants to contaminants via inhalation, EES noted that based on concentrations of volatile contaminants in soil, only naphthalene was at sufficiently elevated concentrations to pose a potential risk to occupants of buildings on site, specifically the Southport nursing home. This was further investigated in the indoor air quality assessment, through which it was concluded that residents at the Southport site were unlikely to be exposed to unacceptable concentrations of volatile contaminants derived from soil vapour.
- EES considered that users of Gasworks Park and residents at the Southport nursing home are “protected…as long as “direct contact” to the gasworks waste layer does not occur”. EES considered direct contact with contaminants in soil was unlikely given the site is “managed”.
- EES concluded that in the Southport site, *“only soil from boreholes BH5 (0.2-0.7m) and BH8 (0.0-0.1m) exceeded the criteria”.* The auditor does not consider this statement is correct, given the analytical data indicates that multiple samples exceeded the criteria, predominantly for PAHs.

Impacts to beneficial uses (land)

- EES concluded the beneficial uses of human health, production of food and fibre, maintenance of highly modified ecosystems, aesthetics and buildings and structures are precluded by soil contamination at the site.
- EES considered that the risks to human health from soil contamination at the site can be managed in the longer term through remediation and management.

Conclusions and recommendations

EES made the following conclusions and recommendations:

- Surface soils at the site are variable. The capping layer, described by EES as comprising brown loam and yellow orange sandy clays was widely contaminated with visible gasworks waste, PAHs and TRH C_{16}-C_{34}. The existing capping layer is inadequate (EES did not elaborate on why the capping was inadequate, but the auditor concurs that the capping layer is inadequate to protect site users potentially being exposed to contaminated soils.
- The auditor noted that EES incorrectly stated that "only soil from boreholes BH5 (0.2-0.7m) and BH8 (0.0-0.1m) exceeded the criteria": based on the analytical data the auditor considers that multiple locations at the Southport Site contained contaminants at concentrations above the relevant criteria.
- Direct contact of site users to contaminated soils was the most likely exposure pathway to be realised, and it was concluded the site should be capped to restrict direct contact.
- The ICMPs for the site should be updated to describe the proposed future management

Auditor's comments on site capping assessment

The site capping assessment provides a reasonable understanding of the contamination status of shallow soils across the site. The scope of work undertaken, including number and location of soil locations, sampling methodologies and analytical schedule were appropriate to meet the objective of providing a preliminary understanding of the condition of shallow soils. Overall, despite the shortcomings in the assessment report, the auditor concurs with EES' conclusions and recommendations.

The auditor notes:

- *EES provided a very detailed report, which at times is difficult to follow. In particular, the risk assessment sections do not clearly lead to the conclusions of the report. During the course of the audit, the auditor provided detailed feedback to EES, and the majority of the auditor's concerns were addressed through this process. While there were still matters that were not addressed, the auditor considers that the body of data is representative of site conditions and is sufficient for reaching conclusions regarding the requirements for remediation and management.*
- *The auditor does not agree with the derivation or application of bioavailability factors in EES 2014A, because of the heterogeneity of the contamination and the PAH fingerprinting analysis that indicated a mixed source (primary gas condensate (tar), secondary gas condensate (spent oxides) and pyrogenic residue (ash, coke, clinker and slag) for the majority of samples. However, in view of the proposal to cap the site or apply other measures to prevent access to contaminated soil (e.g. further testing to identify acceptable areas, or physical restriction such as fencing/planting), the auditor concludes that the uncertainty surrounding bioavailability would not affect the outcome of the audit. In reaching this view, the auditor reviewed the analytical data provided by EES and*

undertook a review of the data provided against published guidelines (refer Section 4.4) and proposed remedial actions. This is discussed in Section 5.

- *EES provided an interpretation of the analytical data in terms of stratigraphic layer. The auditor considered this to be of limited value, given the absence of a defined capping layer and the extensive contamination present in the shallow soils. The auditor reviewed the analytical data provided by EES in terms of soil depth, as discussed in Section 4.4, and undertook a detailed review of borelogs. Based on this information, the auditor concludes that the shallow soils (i.e. less than 0.5 mbgl) across the site are widely contaminated with gasworks waste material (such as coke, slag, ash and tar), and the associated contaminants. The physical description of the soil in the top 0.5 m is variable, and is described as brown loam, orange-yellow sandy clay, brown silty clay, or various other lithologies. The auditor supports the conclusion that the contamination in shallow soils across the site is sporadic and random, and it would appear to be difficult to reliably define and characterise the capping layer.*
- *The limiting contaminants at the site are PAHs, specifically BaP. While concentrations of other contaminants such as TRH and inorganics were detected exceeding the investigation levels, these were comparatively limited in extent compared with PAHs. The majority of PAH contamination is associated with visible gasworks waste and as such it can be assumed that wherever gasworks waste is observed there is the potential for contamination, regardless of the surface soil type. However, there were some instances where PAH contamination was reported in analyses of soil samples without visual evidence, and conversely in some situations there was visual evidence but no contamination detected. This suggests that the contamination may be the result of heterogeneous particulate material (presumably coke and ash) irregularly and likely randomly distributed across the site, rather than being present as homogeneous areas or "hotspots" of significant extent (although it is possible that some such areas do exist).*
- *Overall, the analytical results suggest that the distribution of contamination is widespread, and that it would be difficult to visually identify and delineate areas of contamination. The results indicate that the existing capping does not meet the requirements for long term use of the park for recreational purposes.*
- *The contamination detected may limit the growth of certain plant species. However, while there has historically been failure of some plantings, it has been possible to select plant species that provide an acceptable level of vegetation and amenity for users of the park*
- *Given the random distribution of contamination identified, the auditor queried whether further sampling would provide any beneficial information, or whether it would be more cost effective to consider the entire site contaminated and therefore develop a management strategy accordingly. The auditor discussed this with EES and CoPP's General Manager of City Infrastructure Services in December 2012. CoPP indicated its intent to re-landscape the Gasworks Park (i.e. excluding the Southport Site, the future of which is unknown), and it was considered this course of action encouraged a broader scale approach to capping the site as a management measure, rather than attempting to identify localised areas of the site that might not require capping.*
- *EES subsequently completed a review of possible remedial and management strategies to mitigate the risk to site users from shallow soil contamination, and this is documented in the RAP (discussed further in Section 5.4). The requirements for clean-up, site capping or other management measures have been incorporated into a conceptual Landscape Management Plan (Draft Park Plan) for the site, developed by CoPP's landscape architect in consultation with EES.*

- *Subsequent to this work, consultation with stakeholders has indicated that there is a high priority to minimise loss of trees and disruption to the park that would result from implementation of the Draft Park Plan, and CoPP is considering how this might be achieved. Options that might provide for this are discussed in Section 5.4.2 of this report.*

4.4 Auditor's summary of soil and groundwater results exceeding criteria

As noted in Section 3.1, because EES' soil assessment was undertaken well before the introduction of the NEPM 2013 amendment, EES compared the soil assessment results to NEPM 1999. The auditor did not request that EES amend its report, as this would not alter the overall outcome of the audit and proposed remedial strategy. However, in order to be consistent with the RAP and with current legislation, the auditor undertook a comparison of the data provided by EES (in EES 2014A) with the NEPM 2013. This is discussed in the following sections.

For completeness the auditor has also summarised the groundwater information provided by EES, and has compared the results with the criteria specified in the NEPM 2013 (Schedule B1, Section 2.8). Where appropriate the auditor also considered the groundwater HSLs for vapour intrusion.

4.4.1 Soil

Human health

Table 10 provides a summary of analytes which were detected at concentrations above the human health criteria (NEPM 2013 HIL C or HSL C (Gasworks Park) and HIL A or HSL A (Southport site)). Where criteria were available for both direct contact and vapour intrusion exposure pathways, the lowest value was adopted as a conservative measure. In the soil capping report (EES 2014A, EES evaluated the soil concentrations with respect to soil type. While this can be useful if it is intended that certain soil types will be treated or managed differently, given the most likely exposure pathway by which receptors may be impacted by soil contamination at the site is direct contact with contaminated soils, the auditor considered concentrations of PAHs and BaP in the top 0.5 mbgl of soil across the site as a whole, irrespective of soil type.

Table 10 indicates that almost half the samples analysed from the top 0.5 m of soil contained concentrations of BaP TEQ above the criteria. Concentrations of total PAH, naphthalene, benzene and total cyanide exceeding the criteria were also present in some samples across the site, though not as prevalent as BaP, and BaP is the limiting contaminant (ie determines the requirements for remediation and management). Frequently concentrations of PAHs (including BaP) increased with depth below 0.5 mbgl.

Table 10 Summary of contaminants and samples exceeding human health criteria

Analyte	NEPM HIL/HSL A[6,9] (Southport site)	NEPM HIL C[6,8] (Gasworks Park)	Sample depth interval (mbgl)	# samples exceeding ILs	Concentration range above ILs	Average concentration (all samples)[7]
Total PAH	300	300	0-0.2	2	1744 - 2194	148.8
			0.2-0.5	3	402 – 1570	188.8
			>0.5	26	337 – 28 597[A]	1379.9
BaP TEQ[4]	3	3	0-0.2	17	3.0 - 137.9	9.29
			0.2-0.5	21	3.4 – 189.4	22.4
			>0.5	33	3.027 – 1445	108.8
Naphthalene[5]	3	NL	0-0.2	1 (Southport)	28.9	1.5
			0.2-0.5	1 (Southport)	22.9	3.0
			>0.5	2 (Southport)	4.5, 7	168.2
Total Cyanide[3]	250	240	0-0.2	0	NA	3
			0.2-0.5	3	247 – 763	86.1
			>0.5	4	252 – 4240	285.3
Lead	300	600	0-0.2	0	NA	51.2
			0.2–0.5	2 (Southport) 1 (Park)	466 - 633	126.7
			>0.5	1 (Southport) 1 (Park)	332 - 6720	210.4

NOTES:
All concentrations in mg/kg
"-" All concentrations below criteria
Source: EES 2014A, Tables 4 and 5
NL – not limiting
NA – not applicable (no samples exceeding HIL)
NEPM HIL/HSL A – low density residential
NEPM HIL/HSL C – public open space
Underlined: Average concentration exceeds NEPM HIL A and/or HIL C
[1]. Number of samples analysed for Total CN: 0-0.2 mbgl - 4 samples; 0.2-0.5 mbgl – 24 samples, >0.5 mbgl – 22 samples
[2] Only includes concentrations above the criteria (does not include results below criteria).
[3] Criteria is for free cyanide and results are for total cyanide; free cyanide not analysed. Comparison is therefore conservative. Limited samples analysed for total cyanide (3 samples from 0-0.2 mbgl, 25 from 0.2-0.5 mbgl, 22 from >0.5 mbgl).
[4] BaP TEQ calculated from EES data, in accordance with Table 1A(1) of the NEPM 2013. Where results were <LOR, the LOR was adopted.
[5] From Table 1A(3), criteria for vapour intrusion in sandy soils 0 to <1 mbgl depth. >1 mbgl not limiting soil
[6]. From Table 1A(1), NEPM 2013 (total PAH, BaP TEQ, total CN)
[7] Average (mean) concentration calculated from all analytical results. Where results were below the limit of reporting (LOR), the LOR has been adopted as the representative concentration.
[8]. Applicable to Southport site only, therefore only samples from within Southport area exceeding HIL have been included.
[A] This result was for the sample collected at 0.5-0.6 mbgl, however there was no shallower sample collected. Given the borelog indicates evidence of contamination from 0.4 mbgl, the auditor considers it reasonable to assume the elevated concentration detected was present from approximately 0.4 mbgl.

The auditor did not consider the HSLs for TRH provided in NEPM 2013, as they are intended for petroleum based contamination, rather than mixed source contamination such as gasworks waste. The auditor reviewed the TRH SSTLs that EES derived, but considered them of limited relevance given the prevalence and hence limiting nature of PAH and BaP contamination.

Ecosystems

NEPM 2013 provides limited criteria for ecological protection, as EILs and ESLs. Of those available, naphthalene was detected at concentrations above the criteria in three samples, all from greater than 0.5 mbgl depth (concentration range 527 – 6600 mg/kg), and BaP was detected in almost all samples above the ESL (0.7 mg/kg) for fine soils in an urban residential and public open space land use setting. The auditor did not consider it necessary to derive site-specific criteria for ecological protection, as protection of ecosystems is not the limiting beneficial use on site. The presence of established vegetation across the site, suggests that plant species have been identified that can tolerate the existing soil conditions. On this basis, the Interim Audit assigned a low level of risk associated with protection of ecosystems.

4.4.1 Groundwater

Summaries of groundwater analytical results are presented in Tables 11 to 18 of EES 2013 (groundwater investigation) and Tables T2 to T6 of EES 2014C (supplementary groundwater assessment). Tables 11 and 12 below provide a summary of samples from the 2013 sampling event which exceeded the guidelines for specific analytes. The tables only include those analytes for which there were exceedences of guidelines. This review considers the applicable beneficial uses (based on groundwater Segment A1, in accordance with the Groundwater SEPP) and analytical results; it does not include consideration of whether the beneficial uses are likely to be realised. A discussion regarding the likelihood of beneficial uses being realised, and hence completeness of pathways to receptors is provided in Section 5.3.

On-site

Groundwater samples were analysed from a total of 16 onsite monitoring wells. Concentrations of chloride and sodium exceeded the guidelines for irrigation and drinking water for the majority of wells but it was considered that these would be represented by TDS results, and hence have not been tabulated below.

It can be seen from the results that groundwater at the site contains concentrations of ammonia, total cyanide, fluoride, nitrate, sulphate, TDS, and various metals above the investigation levels. Additionally, groundwater pH was marginally below the drinking water criteria range in six wells (GW05, W19, GW40, GW42D, GW43 and GW44 (not tabulated).

Table 11 Summary of onsite groundwater concentrations and samples exceeding criteria – inorganic analytes

Analyte	Onsite samples exceeding criteria for each beneficial use[3]					Concentration range in onsite wells (mg/L)[2]
	Drinking Water	*Ecosystems*	*Recreation*	*Livestock*	*Irrigation*	
NH_3	GW01, GW02, GW05, GW18, GW19, GW22,GW23, GW24, GW31, GW35, GW39, GW41, GW42D, GW43, GW44	GW01, GW02, GW05, GW18, GW19, GW23, GW24, GW31, GW35, GW39, GW42D, GW43, GW44, ***	GW01, GW02, GW05, GW18, GW19, GW23,GW24, GW31, GW35, GW39, GW42D, GW44	NA	GW01, GW02, GW05, GW18, GW19, GW22, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW42D, GW43, GW44	0.16 – 2 410
Total CN [2]	GW05, GW22, GW24, GW31, GW39, GW44	GW01, GW02, GW05, GW18, GW19, GW22, GW23, GW24, GW31, GW35, GW39,GW41, GW42D, GW44	-	NA	NA	<0.004 - 0.75
Fluoride	GW05, GW31, GW35, GW39	NA	-	GW05, GW31, GW35	GW01, GW02, GW05, GW31, GW35, GW39, GW41	0.2 - 4.5
Nitrate	GW24	NA	-	-	NA	<0.01 - 128.47
Sulfate[1]	GW02, GW05, GW18, GW19, GW24, GW39, GW41, GW42D, GW43, GW44	NA	GW42D	GW02, GW05, GW18, GW19, GW24, GW39, GW42D, GW43, GW44	NA	178 – 14 400
TDS	GW01, GW02, GW05, GW18, GW19, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW42D, GW43, GW44	NA	NA	GW01, GW02, GW05, GW18, GW24, GW35, GW40, GW41, GW42D, GW43, GW44	GW01, GW02, GW05, GW18, GW19, GW22, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW42D, GW43, GW44	596 – 27 000
Al	GW42D	NA	NA	-	-	<0.01 - 0.45
As	GW01, GW02, GW05, GW19, GW22, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW42D, GW43, GW44	GW01, GW02, GW05, GW19, GW22, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW42D, GW44	GW01, GW05, GW19, GW23, GW31, GW35, GW39	GW19, GW23, GW35, GW39	GW01, GW02, GW05, GW19, GW23, GW31, GW35, GW39, GW44	0.003 - 2.06
Bo	-	-	-	-	GW01, GW02, GW05, GW19, GW22, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW43, GW44	0.28 - 3.03
Co	NA	GW01, GW02, GW05, GW19, GW22, GW23, GW24, GW31, GW35, GW39, GW40, GW41, GW42D, GW43, GW44	NA	GW42D	GW19, GW42D, GW43	0.002 - 7.79

Analyte	Onsite samples exceeding criteria for each beneficial use[3]					Concentration range in onsite wells (mg/L)[2]
	Drinking Water	*Ecosystems*	*Recreation*	*Livestock*	*Irrigation*	
Cu	-	GW01, GW02, GW18, GW19, GW22, GW24, GW35, GW39, GW40, GW41, GW42D, GW43, GW44	-	-	-	0.001 - 0.065
Fe	NA	NA	NA	NA	GW01, GW02, GW05, GW19, GW23, GW31, GW35, GW39, GW40, GW42D, GW43, GW44	<0.05 - 255
Mg	NA	NA	NA	GW18, GW42D, GW43	NA	3 - 1060
Mn	GW02, GW05, GW18, GW19, GW35, GW39, GW40, GW42D, GW43, GW44	NA	GW19, GW42D, GW44	NA	NA	0.035 - 24.6
Ni	GW01, GW05, GW19, GW22, GW31, GW35, GW39, GW40, GW42D, GW43, GW44	GW31, GW42D	GW42D	GW42D	GW42D	0.002 - 2.22
Se	GW42D, GW44	-**	-	-	-	<0.01 - 0.01
Zn	-	GW01, GW02, GW05, GW19, GW22, GW31, GW39, GW40, GW41, GW42D, GW43, GW44	NA	-	-	0.01 - 0.143

NOTES:

Source: EES 2014C (results from supplementary groundwater sampling undertaken June 2013).

*EES incorrectly highlighted 17 samples (including "SPLIT") in Table T2 of EES 2014C (supplementary groundwater)

**All results <0.01 mg/L, which is higher than criteria (0.003 mg/L)

*** EES incorrectly highlighted GW22 and GW41 as exceeding the ecosystem criteria for ammonia (criteria 0.91 mg/L, GW22 0.71 mg/L, GW41 0.80 mg/L)

"-" all results below criteria

NA – no criteria

[1] Sulfate as SO_4^-

[2] Application of criteria to total CN, as opposed to free CN is considered to be conservative, as total cyanide analysis includes low toxicity forms of cyanide as well higher toxicity forms (i.e. the less toxic strong metal complexes (i.e. ferricyanides) and the higher toxicity weak acid dissociated (WAD) form). ANZECC indicates the criterion is applicable to un-ionised HCN (i.e. free cyanide). NHMRC 2009 and ADWG 2011 do not specify whether the criteria apply to total or free CN. When considering free CN, 13 samples exceeded the criterion for drinking water, and two samples exceeded the modified criterion for primary contact recreation.

[3] Criteria as per NEPM 13, Schedule B1 Section 2.8

[4] Irrigation criterion adopted for ammonia is the Short Term Trigger Value for nitrogen (5 mg/L), ANZECC 2000 (Volume 3, Section 9.2.6.2); this assumes that ammonia is the major contributor to the measured total nitrogen concentrations in groundwater.

Table 12 Summary of onsite groundwater analytical results and concentrations exceeding criteria – organics analytes

Analyte	Onsite samples exceeding criteria for each beneficial use[3]					Concentration range in onsite wells (mg/L)[1]
	Ecosystems	*Drinking Water*	*Recreation*	*Livestock*	*Irrigation*	
Benzene	GW24, GW44	GW02, GW05, GW23, GW24, GW35, GW39, GW42D, GW44	GW02, GW05, GW23, GW24, GW35, GW39, GW42D, GW44	NA	NA	<0.001-3.38
Ethylbenzene	GW23, GW24*, GW44	-	NA	NA	NA	<0.002-0.052
Toluene	GW44	-	NA	NA	NA	<0.002-0.455
Total xylene	NA	GW24	GW24, GW44	NA	NA	<0.002-1.653
Naphthalene	GW24, GW44	NA	NA	NA	NA	<0.001-6.470
TPH C_6-C_9	GW23, GW24, GW42D, GW44	GW23, GW24, GW42D, GW44	NA	NA	NA	<0.02-5.110
TPH C_{10}-C_{36}	GW02, GW05, GW19, GW23, GW24, GW39, GW42D, GW44	GW02, GW05, GW19, GW23, GW24, GW39, GW42D, GW44	NA	NA	NA	<0.05-116.00

NOTES:

Source: EES 2014C (supplementary groundwater sampling).

"-" all results below criteria

NA – no criteria

[1] includes all concentrations (i.e. above and below criteria)

[2] Criteria as per NEPM 13, Schedule B1 Section 2.8

[3] TPH – results before silica gel clean-up. After silica gel clean up GW23, GW24 and GW44 exceeded the ecosystems and drinking water criteria (concentration range 0.65 – 58.1 mg/L).

* GW24 result <0.1 mg/L (LOR raised)

Off-site

Samples were analysed from a total of 17 offsite wells. EES described the offsite wells as being in three groups: north west, north east and south east (refer Table 4 of EES 2013 (groundwater report)). As with the onsite wells, concentrations of chloride and sodium in the majority of wells exceeded the criteria for irrigation and drinking water. Groundwater pH was below the range for drinking water (pH units 6.5-8.5) in six offsite wells (GW08, GW30, GW09, GW10, GW15, GW25).

The analytical results are summarised in Table 14, and indicate that groundwater quality offsite is variable and can exceed the criteria for protection of beneficial uses. In particular, off site wells that are unlikely to be hydrogeologically connected with the site (i.e. wells that are located beyond the deep sewers to the south east or north west) contain concentrations of total cyanide, various metals, TDS and/or TRH at concentrations exceeding the guidelines. Some of these wells to the north west and to a lesser extent to the south east of the site are beyond the sewers that intercept groundwater and which are believed to effectively hydraulically isolate the site, and it is possible that the contamination in these wells is associated with off-site sources. However, as Golder (2006) noted, CCTV inspection of the sewers indicated only a limited amount of seepage into the sewers, which supported their estimate of just over 2.3 m^3/day of groundwater inflow to the sewers, compared to EES's estimate of 11 m^3/day. Whichever is correct, ultimately the rate of groundwater inflow to the sewer network will depend on how resistive the sewer pipe is to leakage. Noting that these large sewers are gravity sewers and the surrounding groundwater level is above the sewer and the groundwater is drawn down by the sewers, the sewers will be gaining rather than losing, and it can be expected that bypass will not occur. If the groundwater levels were lower beyond these deep sewers, then it would be possible for groundwater to bypass the sewers; however, these situations have not been observed (see below).

The distribution of TDS and ammonia concentrations, both of which may be representative of gasworks contamination, support the scenario of the sewers intercepting groundwater. TDS concentrations in groundwater onsite in the vicinity of the South Yarra sewer ranged between approximately 4 600 mg/L (GW24) to 27 000 mg/L (deep well GW42), consistent with contamination from gasworks waste, whereas TDS in wells immediately southeast of the sewer contain substantially lower TDS concentrations (approximately 150 mg/L to 550 mg/L. Similarly, ammonia concentrations at the south eastern boundary of the site have been reported in the order of 427 mg/L (GW05) to 2410 mg/L (deep well GW42D) on the site in the vicinity of the South Yarra sewer, whereas the maximum ammonia concentration reported in wells beyond the South Yarra sewer to the south east was approximately 0.67 mg/L (June 2013 sampling event).

Golder prepared a hydrogeological conceptual model for the site in 2006[19] which included a review of surrounding groundwater information. Golder concluded that the two main sewers, Hobsons Bay and South Yarra sewers were causing significant drawdown of groundwater levels, and that groundwater flow from the site and from areas beyond the site were towards these sewers. This is supported by the findings of other audits completed in the vicinity of the site[20], which found groundwater flow in the vicinity of the site to be strongly influenced by the Hobsons Bay and South Yarra sewers (refer to figure in Appendix N). Golder concluded that groundwater from the site discharges primarily to the sewer network, and is "unlikely to migrate past the sewers".

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[19] Golder Associates, *Hydrogeological Conceptual Model, Gasworks Park Precinct, Former South Melbourne Gasworks, Graham Street, Albert Park, Victoria,* 28 July 2006 (Golder 2006)

[20] Golder Associates Figure 2, *Regional Groundwater Monitoring Network,* in URS Australia Pty Ltd, *Environmental Audit Report, Albert Park College, 83-85 danks Street, Albert Park, Victoria, EPA Ref 62618-2,* 25 November 2010, PDF page 117, http://apps.epa.vic.gov.au/EnvAuditFiles/53X/62618-2/62618-2_a.pdf

The auditor has considered whether there might be aquitards that would allow groundwater to flow horizontally independent of the deep sewers; however, there is no evidence that this is the case. It is noted that the groundwater levels measured in both deep and shallow bores are similar (EES 2013, EES 2014C).

The auditor concludes that, because the groundwater levels are lowest in the vicinity of the deep sewers and therefore groundwater flows from the site and from areas beyond the site are towards the deep sewers, it is unlikely that groundwater contamination migrates past the sewers.

There is an area of groundwater off site to the north east of the site across Richardson Street which is contaminated with ammonia, total cyanide, TRH, benzene, ethylbenzene, and naphthalene, with reasonably high TDS concentrations. This is consistent with the groundwater flow being toward the northern (off site) section of the deep sewer which runs along the eastern boundary of the site. In this respect, EES (2013) noted that '*GW8, GW37, GW38 (and to a lesser extent GW7 and GW28), close to Richardson Street have elevated NH4+ and SO42-',* and that *'the groundwater flow direction is… approximately parallel to Richardson Street*', and that as such …*'it is possible that these wells have been impacted by contaminated groundwater migrating from on site'*. However, there is a shallow sewer (above the water table) that runs along Richardson Street and it is possible that ammonia and sulphate contamination occurs through leakage from this sewer. The EES report does not reach a firm conclusion as to the source of ammonia in off-site groundwater wells to the northwest and northeast of the site, but suggests that this could be due to an on- or off-site source(s). The auditor has considered this, and concludes that it is most likely that, because other gasworks related contaminants (cyanide, BTEX, TRH and PAHs) are present, the contamination is of gasworks origin and arises from the site. It would be possible to carry out an isotopic analysis to confirm the source of ammonia; however, unless it is necessary to unequivocally confirm the source in deciding the groundwater management strategy, there is a low priority for undertaking this additional work.

As an assessment of risk to human health with respect to the beneficial uses of land should also consider the exposure pathway of inhalation, contamination of groundwater with volatile analytes is relevant[21]. The NEPM 2013 provides HSLs for TRH (F1 and F2) and BTEX. The HSLs for TRH are not applicable to non-petroleum sources such as gasworks waste[22], and therefore are not applicable. The HSLs for toluene, ethylbenzene and xylenes can be applied, but are not limiting, as the HSL exceeds the groundwater solubility limit. HSLs are also provided for benzene for low and high density land use scenarios only (BTEX and TRH are not limiting for recreational / open space). All concentrations of benzene were below the HSL for benzene for residential land use (0.8 mg/L[23]), with the exception of one monitoring well: GW44D (benzene 1.12 mg/L), which is situated on the southeast of the Southport site (refer Figure 6). Because GW44D is a deep well, installed to target the base of the Brighton Group Aquifer, volatiles in this well would not adversely affect human health.

The auditor concludes that the concentrations of benzene detected in groundwater in offsite wells that might be attributed to the site do not pose a significant risk to human health via inhalation, noting:

- Indoor air quality monitoring undertaken by EES at the Southport site did not detect benzene or other volatile CoPC at unacceptable levels;

[21] Risk associated with extractive beneficial uses of groundwater are discussed in Section 5.

[22] CRC Care Publication No. 10 Health Screening Levels for Petroleum Hydrocarbons in Soil and Groundwater. Part 2: Application Document (2011)

[23] for groundwater between 4 to <8 mbgl, sand matrix

- The sewer is ultimately capturing contaminated groundwater from the site, and groundwater beneath offsite residential properties did not contain concentrations of benzene above the HSLs; and
- Groundwater is at considerable depth and biodegradation can be expected to reduce the concentrations of benzene migrating to the surface.

4.5 Quality control and quality assurance

The auditor undertook a review of the Quality Assurance and Quality Control (QAQC) documentation presented by EES, and reviewed EES' procedures to verify the integrity of the data presented. A summary of this review is provided in Appendix J.

In reviewing the site capping report (EES 2014A) and RAP (EES 2014C), the auditor found that there were a number of uncertainties and areas where the report could be improved. Notwithstanding this, the auditor is satisfied that the analytical results reported are representative of conditions of soil, groundwater and indoor air at and in the vicinity of the site at the time of the assessment, and that the methodology adopted by EES for the assessment of soil, groundwater and indoor air quality was generally appropriate and suitable for forming an opinion on the risk posed by the contamination at the site.

Table 13 Summary of offsite groundwater analytical results and samples exceeding criteria – inorganic analytes

Analyte	Offsite groundwater samples exceeding criteria for each beneficial use[3, 4]					Concentration ranges in offsite wells (mg/L)		
	Ecosystems	*Drinking Water*	*Recreation*	*Livestock*	*Irrigation*	**North east**	**North west**	**South east**
NH_3	GW06, GW32, GW33, GW34, GW07, GW08, GW26, GW28, GW37, GW38, GW25	GW06, GW32, GW33, GW07, GW08, GW26, GW28, GW37, GW38, GW25	GW32. GW33, GW07, GW08, GW28, GW37, GW38	NA	GW32, GW33, GW34, GW36, GW07, GW08, GW26, GW28, GW30, GW37, GW38, GW09, GW10, GW25	0.05 – 1 150	<0.01 - 16.3	<0.01 - 0.67
Total CN[2]	GW06, GW32, GW33, GW34, GW36, GW007, GW08, GW28, GW29, GW37, GW38, GW15, GW25	GW32, GW34, GW37, GW38	-	NA	NA	<0.004 - 0.16	0.005 - 0.255	<0.004 - 0.004
Fluoride	NA	GW32. GW33, GW34, GW36, GW07, GW28, GW30	-	GW32, GW34, GW36, GW07*	GW06, GW32, GW33, GW34, GW36, GW07, GW28, GW39*, GW37, GW38*	0.3-2.0	1.4 – 3.0	<0.1-0.5
Nitrate	NA	GW29, GW09	-	-	NA	0.04 – 71.3	0.18 – 20.3	0.04 – 115.6
Sulfate[1]	NA	GW33, GW34, GW36, GW08, GW37, GW38	-	GW33, GW34, GW08, GW38	NA	184 - 2070	90 – 2430	72 - 314
TDS	NA	GW06, GW33, GW34, GW36, GW07, GW08, GW26, GW28, GW29, GW30, GW37, GW38	NA	GW33, GW34, GW36, GW38	GW06, GW32, GW33, GW34, GW36, GW07, GW08, GW26, GW28, GW29, GW30, GW37, GW38, GW09, GW10, GW15, GW25	1180 - 3440	936 – 6390	520 - 680
As	GW32, GW33, GW34, GW36, GW07, GW08, GW26, GW28, GW30, GW37, GW38, GW09, GW10, GW25	GW32, GW33, GW34, GW36, GW07, GW08, GW26, GW28, GW30, GW37, GW38, GW09, GW10, GW25	GW32, GW34, GW08, GW28, GW37, GW38	GW32, GW34	GW32, GW34, GW08, GW28, GW37, GW38	<0.001 - 0.365	0.002 - 1.45	<0.001 - 0.034
Bo	NA	GW33, GW34	-	GW34	GW06, GW32, GW33, GW34, GW36, GW07, GW08, GW28, GW29, GW30, GW37, GW38, GW09, GW15, GW25	0.47-0.95	0.99 - 8.25	0.34 - 1.51
Co	GW33, GW34, GW36, GW07, GW08, GW26, GW29, GW30, GW37, GW38, GW10, GW15, GW25	NA	NA	-	-	<0.001-0.034	<0.001 - 0.015	<0.001 - 0.002

Analyte	Offsite groundwater samples exceeding criteria for each beneficial use[3, 4]					Concentration ranges in offsite wells (mg/L)		
	Ecosystems	*Drinking Water*	*Recreation*	*Livestock*	*Irrigation*	**North east**	**North west**	**South east**
Cu	GW06, GW32, GW33, GW34, GW36, GW07, GW08, GW26, GW29, GW30, GW38, GW09, GW10, GW15, GW25	-	-	-	-	<0.001-0.004	0.002 - 0.006	0.002 - 0.003
Fe	NA	NA	NA	NA	GW32, GW34, GW36, GW07, GW08, GW26, GW28, GW30, GW37, GW38, GW10, GW25	<0.05 - 36.3	<0.05 - 2.33	<0.05 - 0.96
Mn	NA	GW08. GW26, GW38	-	NA	NA	0.17-3.64	0.07 - 0.421	0.017 - 0.102
Ni	GW34, GW08	GW06, GW32, W33, GW34, GW36, GW07. GW08, GW26, GW29, GW30, GW09, GW10, GW15, GW25	-	-	-	0.003 - 0.1	0.025 - 0.074	0.036 - 0.067
Se	**	**	-	-	-	<0.01	<0.01	<0.01
Zn	GW06, GW32, GW33, GW36, GW07, GW08. GW05, GW29, GW30, GW37, GW09, GW10, GW15, GW25	-	NA	-	-	<0.005 - 0.137	0.01 - 0.035	0.031 - 0.067
Pb	GW32	GW32	-	-	-	<0.001 - 0.002	<0.001 - 0.011	<0.001

NOTES:
Source: EES 2014C (results from supplementary groundwater sampling undertaken June 2013).
Offsite wells as defined in Section 5.2.4 and Tables T3-T5 of EES 2014B:

- North east wells: GW07, GW08, GW26, GW38, GW30, GW37, GW38
- North west wells: GW06, GW32, GW33, GW34, GW36
- South east wells: GW09, GW10, GW15, GW25

* Result at LOR
**All results <0.01 mg/L, which is higher than or equal to criteria (ecosystems 0.003 mg/L, drinking water 0.01 mg/L)
"-" all results below criteria
NA – no criteria
[1] Sulfate as SO_4^-
[2] Application of criteria to total CN, as opposed to free CN is considered to be conservative, as total cyanide analysis includes low toxicity forms of cyanide (such as the strong metal complexes (e.g. ferricyanides)) as well higher toxicity forms (WAD and free cyanide)). ANZECC indicates the criterion is applicable to un-ionised HCN (i.e. free cyanide). NHMRC 2009 and ADWG 2011 do not specify whether the criteria apply to total or free CN. When considering free CN, 13 samples exceeded the criterion for drinking water, and two samples exceeded the modified criterion for primary contact recreation.
[3] Criteria as per NEPM 13, Schedule B1 Section 2.8
[4] A total of 17 wells were sampled and analysed for all contaminants of concern
[5] Irrigation criterion adopted for ammonia is the Short Term Trigger Value for nitrogen (5 mg/L), ANZECC 2000 (Volume 3, Section 9.2.6.2); this assumes that ammonia is the major contributor to the measured total nitrogen concentrations in groundwater.

Table 14 Summary of offsite groundwater analytical results and concentrations exceeding criteria – organic analytes

Analyte	Number of samples exceeding criteria[3, 4]					Concentration range in offsite wells (mg/L)[1]		
	Ecosystems	*Drinking Water*	*Recreation*	*Livestock*	*Irrigation*	**North east**	**North west**	**South east**
Benzene	-	GW32, GW08, GW37, GW38	GW32, GW08, GW37, GW38	NA	NA	<0.001 - 0.269	<0.001 - 0.069	<0.001
Ethylbenzene	GW38	-	NA	NA	NA	<0.002 - 0.015	<0.002 - 0.003	<0.002
Total xylene	NA	-	GW38	NA	NA	<0.004 - 0.119	<0.004	<0.004
Naphthalene	GW38	NA	NA	NA	NA	<0.007 - 0.134	<0.007	<0.007
TPH C_6-C_9 [3]	GW38	GW38	NA	NA	NA	<0.02 - 0.53	<0.02 - 0.07	<0.02
TPH C_{10}-C_{36} [3]	GW08, GW37, GW38	GW08, GW37, GW38	NA	NA	NA	<0.05 - 11.9	<0.05 - 0.17	<0.1 - 0.13

NOTES:
Source: EES 2014C (supplementary groundwater sampling).
Offsite wells as defined in Section 5.2.4 and Tables T3-T5 of EES 2014B:

- North east wells: GW07, GW08, GW26, GW38, GW30, GW37, GW38
- North west wells: GW06, GW32, GW33, GW34, GW36
- South east wells: GW09, GW10, GW15, GW25

"-" all results below criteria
NA – no criteria
[1] includes all concentrations (i.e. above and below criteria)
[2] Criteria as per NEPM 13, Schedule B1 Section 2.8
[3] TPH – results before silica gel clean-up. After SG clean up only TPH C_{10}-C_{36} for GW38 (0.91 mg/L) exceeded criteria
[4] A total of 16 groundwater monitoring wells were sampled and analysed on site.

5. Assessment of risk to beneficial uses

5.1 Methodology for the assessment of risk

The approach taken for assessing the risk to beneficial uses involved the following:

- Consideration of the beneficial uses precluded by soil and/or groundwater contamination on and offsite, based on soil, groundwater and indoor air analytical results.
- Identification of the different exposure pathways by which contamination might affect the various beneficial uses (i.e. whether exposure pathways are likely to be complete or incomplete), including development of a conceptual risk model.
- Review of management and remedial options proposed by EES to address the higher risk issues.
- With consideration of the additional soil and groundwater data, review and assessment of the likelihood of each of the higher risk scenarios occurring in which contamination would give rise to a significant effect on the beneficial uses, and the magnitude of that effect. This considered the existing controls that were in place (e.g. the ICMPS) and the proposed remedial works and management strategies to be implemented as outlined in the RAP. Revision of the conceptual risk model.

The descriptors defining the likelihood of a scenario occurring and the severity of effect and the resulting level of risk are defined in the risk assessment matrix shown in Appendix C. These descriptors were based on the Australian Standard *Risk Management* (AS 4360: 2004)[24] and the ranking of risk for various combinations of likelihood and severity was based on the judgement of the auditor. This was considered to be an adequate approach for the audit where only a relative ranking is required to focus further assessment. It is possible that other risk rankings could be adopted. The relevance and appropriateness of the descriptors that were adopted in the Interim Audit were reviewed based on the further soil and groundwater data. Some minor adjustments were made to the wording to better reflect the nature of contamination (i.e. soil or groundwater), but no changes were made to the severity or likelihood scales.

The approach and findings are outlined in the following sections.

5.2 Beneficial uses precluded

In order to undertake an assessment of risk to beneficial uses of land and groundwater, those beneficial uses precluded by concentrations of contaminants in soil, groundwater and indoor air must first be identified. The following provides a summary of the beneficial uses of land and groundwater that are precluded, based on the analytical data, as summarised in Section 4.4.

5.2.1 Land

Based on the soil analytical results, the onsite beneficial uses of human health (receptors park users and workers), aesthetics, highly modified ecosystems and production of food, flora and fibre are precluded.

There were no offsite beneficial uses precluded by soil contamination.

5.2.2 Groundwater

Table 15 shows the beneficial uses precluded onsite and offsite, and whether these beneficial uses are likely to be realised. There are no onsite beneficial uses likely to be realised given the

[24] This is consistent with the approach outlined in ISO31000

ongoing use of the site as a park, which is managed by CoPP (i.e. groundwater extraction can be prevented).

Offsite, the only beneficial uses that may be realised (albeit a low likelihood), should the current hydrogeological conditions continue (i.e. sewers continue capturing groundwater from the site, ongoing use as a park managed by CoPP) are primary contact recreation and agriculture, parks and gardens. These beneficial uses could be realised if offsite residents extract contaminated groundwater to fill a swimming pool (recreation) or water gardens. The presence of a reticulated water supply makes it unlikely residents would extract water for drinking purposes. Stockwatering is considered to not be a relevant beneficial use, given the urban setting of the site. Buildings and structures is considered to not be a relevant beneficial use, as the depth to groundwater makes it highly unlikely that groundwater would impact on buildings and structures.

The beneficial use maintenance of ecosystems is not currently being realised, as contaminated groundwater is being captured by the sewer network. EES concluded that if the sewers were repaired and natural groundwater flow towards Port Philip Bay restored, the time it would take for contaminants from the site to migrate to the Bay could be in the order of thousands of years, during which time attenuation and dilution would reduce the contaminant load to negligible concentrations. The auditor concurs that there is a low risk to receiving waters.

Table 15 Beneficial uses precluded by groundwater contamination and limiting contaminants

Beneficial Use		On-site	Limiting contaminants[1]	Off-site	Limiting contaminants[1]
Maintenance of ecosystems[2]		○	NA	○	NA
Potable water supply	Desirable				
	Acceptable	○	Ammonia, total and free cyanide, TDS, benzene, total xylene, TRH C_6-C_9, TRH C_{10}-C_{36}	○	Ammonia, total cyanide, TDS, benzene, TRH C_6-C_9, TRH C_{10}-C_{36}
Agriculture, parks and gardens		○	TDS	●	TDS
Stock watering		○	TDS	○	TDS
Industrial water use		○	TDS	●	TDS
Primary contact recreation		○	Ammonia, benzene, xylenes, naphthalene	●	Ammonia, benzene, naphthalene,
Buildings and structures		○		○	

NOTES:
[1] Only those contaminants considered likely to originate from the site have been included.
[2] Beneficial use maintenance of ecosystems not relevant on site as no surface water bodies present on site.
Empty cell: Land SEPP does not require the beneficial use to be protected

○ Beneficial use precluded by contamination in the vicinity of the site, but unlikely to be realised

● Beneficial use precluded by contamination in the vicinity of the site, and may be realised

5.3 Exposure pathway analysis

This section discusses the pathways by which the beneficial uses nominated by the SEPPs could be impacted. As part of this assessment, the potential receptors to contamination must be identified. A preliminary analysis was undertaken as part of the Interim Audit, which considered

various water, soil and vapour mediums, as well as chemical release and transport mechanisms. The exposure pathways were examined at a high level. Each pathway was compared to the SEPP relevant to the receptor. In this way, all beneficial uses were systematically considered to ensure that all uses were included and that the boundaries between SEPP jurisdictions were clearly defined.

The Interim Audit analysis considered the exposure pathways, such as how contamination of land and groundwater at the site may impact protected uses at the site and offsite. In carrying out this analysis, all protected beneficial uses within the audit area were considered, however those uses that were likely to be realised formed the focus for further assessment (refer Table 5 to Table 8 in Section 3). Detailed exposure flowcharts were developed for the following scenarios, and presented in the Interim Audit (Appendix A). The exposure pathways identified in the Interim Audit are summarised as follows:

1. Risk posed by contaminated soil to onsite land beneficial uses;
2. Risk posed by contaminated soil/groundwater to onsite groundwater beneficial uses;
3. Risk posed by contaminated soil/groundwater to offsite groundwater beneficial uses (uses close to the site);
4. Risk posed by contaminated soil/groundwater to offsite groundwater beneficial uses (uses far from the site)[25]
5. Risk posed by contaminated soil/groundwater to offsite land beneficial use (uses close to the site);
6. Risk posed by NAPL to onsite land beneficial uses;
7. Risk posed by NAPL to onsite groundwater beneficial uses;
8. Risk posed by NAPL to offsite land beneficial uses (near the site);
9. Risk posed by NAPL to offsite groundwater beneficial uses (uses close to the site); and
10. Risk posed by NAPL to offsite groundwater beneficial uses offsite (uses far from the site)[26].

It was recognised in the Interim Audit that impacts associated with NAPL (in groundwater) can be similar to those associated with contaminated groundwater. The investigations undertaken since the interim audit did not identify the presence of NAPL in groundwater. On this basis it is considered the previously identified scenarios specifically related to NAPL (i.e. scenarios 6 to 10 in the Interim Audit) will be adequately covered by consideration of risks associated with contaminated soil and groundwater (as per scenarios 1 to 5 of the Interim Audit).

The Interim Audit analysis yielded more than 260 combinations of receptors, general exposure pathways and relevant beneficial uses to be protected. These were assessed individually for the likelihood of exposure to contaminants, consequence and hence risk level associated with soil and groundwater contamination sourced from the site. The scenarios were provided in a detail matrix in the Interim Audit. All scenarios were reviewed as part of the second phase, to assess the relevance in light of the additional data collected by EES and future management of the site. Particular focus was given to those scenarios identified as posing a ‘medium’ level risk.

[25] Potential impacts far from the site boundary are not strictly included within the agreed audit scope, however they were considered for completeness of the risk assessment.

[26] Potential impacts far from the site boundary are not strictly included within the agreed audit scope, however they were considered for completeness of the risk assessment.

5.3.1 Nature and severity of exposure to contaminants

The preliminary assessment of the consequence (severity) of exposure to contamination undertaken in the Interim Audit was refined based on the additional soil and groundwater data provided by EES, as well as judgement of the auditor and his team. For each scenario the severity of exposure remained largely unchanged, as the nature and concentrations of limiting contaminants identified by EES were largely consistent with Golder's findings. In general, the limiting contaminants were confirmed to be those typically associated with former gasworks operations/wastes, such as PAHs, petroleum hydrocarbons, cyanide, ammonia, nitrate, sulfate and sulphide, metals, salts and pH.

The following was considered when determining the severity of effect:

- People (mainly human health);
- Financial impact of damage to assets and heritage; and
- Environment (actual impact on ecosystems, as distinct from regulatory compliance).

5.3.2 Likelihood of exposure to contaminants

The likelihood of receptors being exposed to contaminants under each scenario with the site in its current state (i.e. without any remediation or management measures being implemented) were reviewed in light of the additional data, giving consideration to the following:

- Depth and associated accessibility of soil contamination;
- Lateral extent of groundwater contamination (and hence whether additional potential receptors exist that were not identified in the Interim Audit); and
- Proposed future users of the site, noting that it is intended that the use of the Gasworks Park will continue as at present, and the Southport site will continue in the immediate future as a residential nursing home.

The likelihood of exposure was then re-evaluated in light of the remedial and management measures proposed by EES.

5.3.3 Review of medium risk scenarios identified in the interim audit

The interim audit identified five scenarios under which it was considered a medium risk[27] was posed to users of the site and surrounds.

- Exposure of occupants/subsurface workers to volatile emissions migrating from contaminated soil and/or groundwater into onsite buildings, structures and excavations;
- Exposure of recreational users of the site through direct contact with contaminated soil and gasworks waste;
- Extraction of contaminated groundwater for onsite irrigation;
- Exposure of nearby residents to contaminated groundwater via extraction for drinking, irrigation and recreational (i.e. filling swimming pools) uses;
- Exposure of on and offsite subsurface works, and humans undertaking works on the sewer to contaminated soil (onsite) and/or groundwater (on and offsite).

EES' investigations largely confirmed the medium risk ranking of these scenarios, with the exception of occupants of buildings onsite being exposed to harmful levels of volatile emissions. EES' indoor air quality assessment (EES 2012) concluded that building occupants were unlikely to be exposed to unacceptable levels of gasworks-related volatile contaminants derived from

[27] All other scenarios considered identified a 'low' or 'negligible' risk; there were no 'high' risk scenarios identified.

contaminated soil and/or groundwater. The auditor concurs with this conclusion, and as such concludes that this is a low risk scenario.

A more detailed review of these medium risk scenarios, taking into account the proposed remedial and management strategies which will represent the ongoing condition of the site, is presented in Section 5.5.

5.3.4 Conceptual risk model prior to remediation

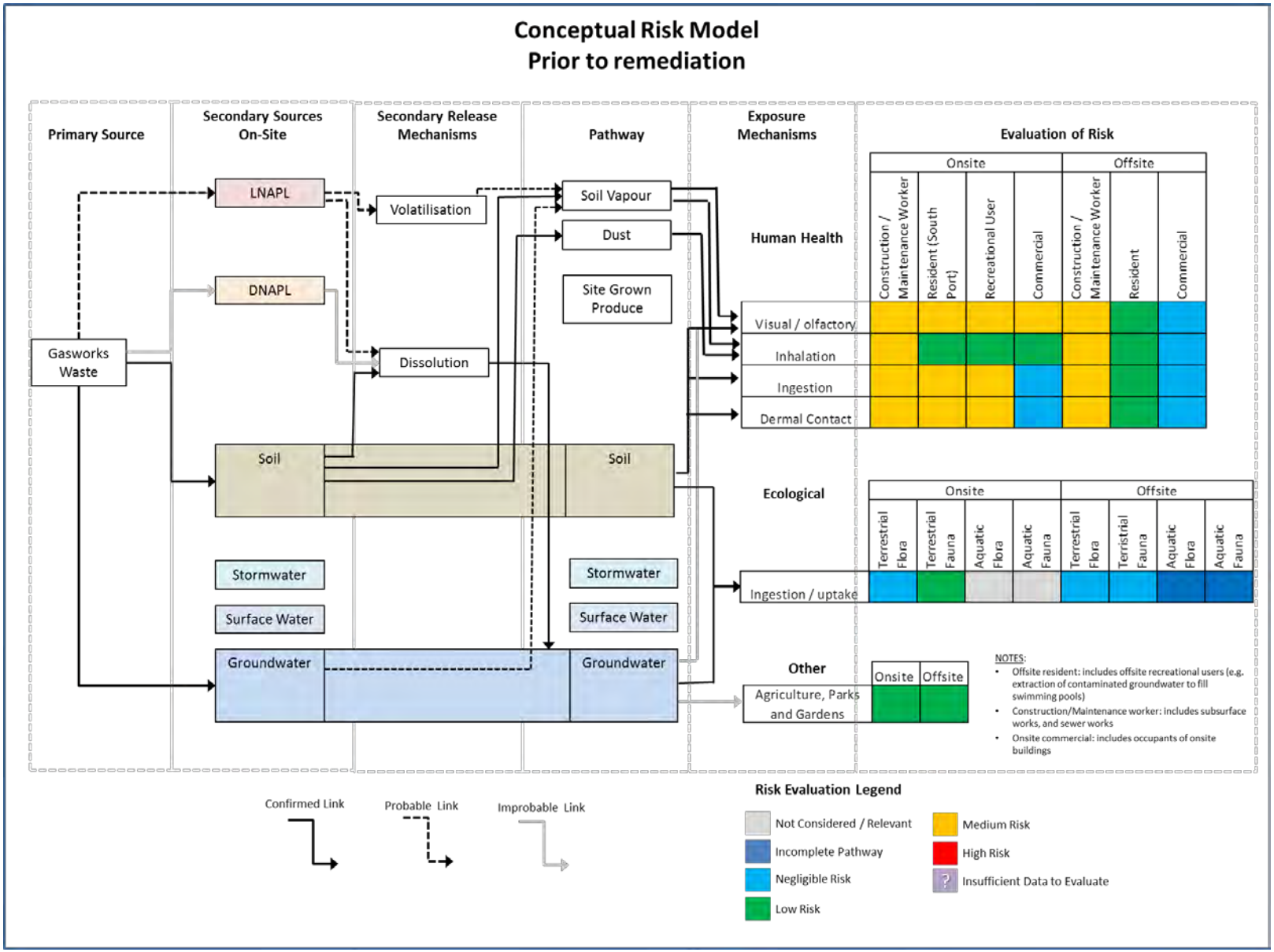
The exposure pathway analysis, likelihood, severity of consequence and risk profile can be summarised as a conceptual risk model (CRM) for the site. Figure 5-1 summarises the information provided in the initial screening risk assessment (provided in the Interim Audit, Appendix A), including the contamination sources (i.e. gasworks waste), release mechanisms, pathways by which receptors may be exposed, and a summary of risk.

The CRM summarises the medium risk scenarios that apply with the site in its current form, namely:

- Exposure of occupants/subsurface workers to volatile emissions migrating from contaminated soil and/or groundwater into onsite excavations;
- Exposure of recreational users of the site through direct contact with contaminated soil and gasworks waste;
- Exposure of nearby residents to contaminated groundwater through extraction and use of groundwater for garden watering and filling of swimming pools;
- Exposure of workers during onsite and offsite subsurface works, including work on the sewers, to contaminated soil (onsite) and/or groundwater (on and offsite).

To address the medium risks, EES proposed remediation and management strategies to address soil and groundwater contamination, and reduce the risk to site and surrounding users to an acceptable level. These measures, and the auditor's review of the proposed strategies are discussed in Section 5.4.

Figure 5-1 Conceptual risk model prior to remediation



5.4 Proposed remedial actions to address the higher risk issues

EES has prepared a RAP (EES 2014B), summarising the soil and groundwater contamination at and surrounding the site, and providing a review of possible remediation and/or management strategies. This section outlines the auditor's review of EES' RAP, and assessment of risk to onsite and offsite beneficial uses, based on the recommended approach.

5.4.1 Auditor's considerations in reviewing the RAP

In reviewing the RAP (EES 2014B) and the proposed remedial strategy involving remediation and management of soil and groundwater contamination, the auditor has considered the following:

- It is essential that:
  - The remedial strategy will reduce the risk to an acceptable level that contamination in soil and/or groundwater at the site poses to persons and the environment, both on site and off site, in both the short and long term.
  - Implementation of the remedial strategy will not pose an unacceptable risk to human health or the environment.
- It is important that:
  - The remedial strategy is logistically and financially viable;
  - The park is retained as a community asset;
  - The extent of disruption to park usage is minimised;
  - The remediation strategy accords with the principles of sustainable remediation. In simple terms, the auditor sees that this means that the strategy should seek a balance between the various environmental, social and economic factors. For example, it is desirable to avoid excavating large volumes of contaminated soil and disposing of this off site, if an alternative that avoids this can achieve an acceptable environmental and social solution.

The following sections consider the various alternative remedial strategies proposed by EES to address soil and groundwater contamination at the site, and the process that EES has applied in selecting a preferred strategy.

5.4.2 Management of soil contamination

EES identified and discussed a number of possible remedial strategies that might be used to reduce the risk to an acceptable level posed by soil contamination at the site to on-site users (human health and ecosystems). Options discussed include capping and isolation, on-site treatment (bioremediation and/or thermal treatment), offsite treatment, and offsite disposal to landfill (refer Section 4.3, Table 7 of EES 2014B).

EES then ranked each remediation technology (Section 4.3, Table 8 of EES 2014B) with respect to whether it was protective of human health and the environment (both onsite and offsite), easily maintained and reliable, and logistically and financially viable. There was no discussion provided as to how the relative rankings were derived, and the auditor assumes that the rankings were subjective.

EES concluded that "capping and isolation" is the most practical way of managing the contaminated soil onsite, noting:

- Capping the site can meet all of the option ranking criteria: being protective of human health and the environment, reliable and easy to maintain, logistically viable, and low to medium cost.

- Capping the site can be “protective of human health including on-site workers and community near the site” in the short and long term, as long as the CMPs are complied with.
- Capping the site would not result in a significant reduction in soil contamination, and this would remain and form an ongoing source of groundwater contamination.

Following the determination that capping the site is the most appropriate approach, the RAP then outlines a hierarchy of remedial measures that would apply to the various areas of the park, such as new playgrounds, existing buildings, existing and new mounding, and so forth (Section 5.3.4, Table 11, EES 2014B). The primary measure recommended by EES is to cap the site with a minimum of 0.5 m clean fill material, underlain by a warning liner. Other options (such as 0.2 m clean fill beneath an impermeable layer (e.g. pavement or decking)) are also allowed, and the RAP does not make it clear as to which of the proposed options will be implemented. The RAP also allows for further validation sampling to be undertaken in areas where there may be a need to retain soil. This allows for sampling the top 0.5 m of soil, to assess whether it is of suitable quality for retention.

The auditor sought clarification from EES on where each remedial measure is to be applied, and EES provided the auditor with a draft concept plan for the site which shows that a 0.5 m cap is to be applied to the majority of the site (refer Appendix L)[28], and that the remaining areas are to be covered with a minimum of 0.3 m clean fill material, underlain with a liner. Areas of existing bluestone paving are to be retained. The auditor understands the plan provided is conceptual and changes may occur. As noted in Section 2.3, subsequent to the release of the Draft Park Plan and in response to community concerns surrounding loss of trees and temporary closure of the park, CoPP is considering the feasibility of options that might reduce the loss of trees and allow use of the park to be less disrupted while works are carried out. This is discussed in Section 5.4.2 and Section 6.1.1

EES indicated that regardless of the strategy adopted, a final, detailed remediation plan will be provided to the auditor for review and endorsement prior to commencing the remedial works. This had not been provided to the auditor at the time of completion of this audit, and it has been included as one of the auditor’s recommendations (refer Section 6.2).

The RAP included soil quality objectives for soil that is to be retained on site or imported to the site, and will remain as shallow soil (ie will form part of the capping system). For this purpose, EES adopted the NEPM 2013 HIL-A (residential, applicable to the Southport site) and HIL-C (parks, recreational open space and playing fields) criteria for protection of human health, with consideration to the NEPM 2013 management limits for TRH[29] for soils that are to be retained on site. The NEPM 2013 EILs were adopted for maintenance of ecosystems.

EES indicated that soils imported to the site for the purposes of capping must firstly meet the requirements of EPA IWRG621[30]. These criteria are more conservative than the abovementioned NEPM 2013 objectives; therefore by meeting the IWRG621 criteria the soil quality objectives above will be met. The auditor notes that EES does not clearly define whether the IWRG621 criteria apply just to material being imported to the site (as is appropriate), or to existing soils onsite (which is not necessary). The auditor considers that application of the IWRG621 to imported soils, and adoption of the NEPM 2013 soil quality objectives for residential and park land use is appropriate.

[28] Email correspondence from EES 10 and 11 December 2013.

[29] NEPM 2013 provides management levels for TRH in Schedule B1, Table B(7).

[30] Industrial Waste Resource Guidelines (IWRG), Publication IWRG621, Soil Hazard Categorisation and Management, June 2009

A limited discussion on requirements for site, community, environment, contractor and health and safety management during remedial works was provided in Section 7 of the RAP (EES 2014C). EES made reference to updated Interim Contamination Management Plans (ICMPs), and provided the auditor with an updated Contamination Management Plan for the Gasworks site which the auditor understands will replace the ICMP (refer Section 5.4.4). It is understood EES intends to prepare a similar CMP for the Southport site.

Auditor's comments on EES' decision making and conclusions regarding the preferred strategy for remediation and management of soil contamination

(a) Remedial strategy recommended by EES

In undertaking his review of the RAP, the auditor also considered EES' emails of 10 and 11 December 2013, and the draft Park Plan (Figure 11). The auditor understands that initially the intent was to cap the majority of the site as a single event with 0.5 m clean soil (resulting in full closure of the park for approximately a year, and removal of all existing vegetation), with the exception of a number of minor areas abutting existing structures that are to be capped with 0.3 m soil underlain by a geotextile liner, and the existing bluestone paving which is to be retained. Subsequent to the community raising concerns regarding the proposed approach of capping the site, CoPP is evaluating whether to undertake further soil testing on certain areas of the site, to establish whether the surface soils (i.e. <0.5 mbgl) can be retained. Regardless, the intent of the remediation strategy, which is to provide a barrier of a minimum of 0.5 m thickness of clean soil (whether imported or existing) or alternative measure to provide a barrier to soil that exceeds the contaminant criteria for open space, remains the same. In view of this the auditor has assumed that, while some aspects of the conceptual landscape plan may change, the overall approach and intent of the remediation will not change.

The auditor has considered the information provided by EES and the various remedial options that can be applied, and concludes that the remedial strategy recommended by EES is able to achieve an outcome that poses a low risk to beneficial uses for the current use of the site, and can be preferred over other remedial options.

However, the auditor considers that the decision making process applied by EES was not well reasoned and the basis for selecting the preferred option was not clear. The auditor sought clarification of various matters from EES, and undertook an independent high level assessment of options to confirm that the option selected by EES can be preferred over other options. The limitations and the auditor's considerations are as follows.

(b) Need for remediation

EES does not clearly define the current level of risk posed by the contamination at the site. EES indicates that the risk is not high in the short term, but concludes in its evaluation of potential transport mechanisms and exposure pathways (Table 6, EES 2014B) that there is an increased risk to receptors in the long term if the site is to remain in its current state, and the risk is "low to medium". While the discussion in the EES report does not provide a consistent analysis of the level of risk, the auditor understands that EES concludes that the risk is not high in the short term (e.g. less than 5 years), but is unacceptable in the long term and hence it is necessary to undertake the remedial work that EES proposes.

In evaluating the EES conclusion, the auditor notes:

- *BaP is the contaminant of greatest concern.*
- *The average BaP TEQ concentration in the top 0.5 mbgl of soil is approximately 15 mg/kg (from data provided in EES 2014A). The random nature of the contamination is such that it could be inferred that some areas of the site contain much less than the average concentration of BaP, and some contain concentrations a magnitude higher. The auditor*

considers that the nature of the activities at the site are such that they are generally distributed across the site rather than being intensive use of a particular area, and thus it is appropriate to consider the average concentration rather than the concentration in a localised area. The auditor notes that the average concentration of BaP is in the order of five times the NEPM 2013 HIL-D criteria for BaP TEQ (3 mg/kg), and this supports the conclusion that the contamination is not acceptable in the long term, and remedial action is required. Because with BaP the likelihood of adverse effects is dependent on the length of exposure, in the short term (e.g. 5 years) it is extremely unlikely that adverse effects would be observed and it can be concluded that there is not an urgent need for remedial action, but nevertheless remedial action is required in the longer term.

- *EES has suggested that the nature of the BaP could be such that it has low bioavailability and hence low toxicity and would not present an unacceptable risk. The auditor has reviewed the information and notes that while some of the BaP is likely to have low toxicity, it is technically difficult to confirm this and concludes that, because of this uncertainty, action to reduce the potential for exposure is required.*
- *The risk posed by BaP depends on the extent of exposure that will occur and its duration. There are factors that will reduce the exposure from that assumed in setting the Health Investigation Levels for BaP, for example the park is grassed and the nature and duration of the activities and involvement of very young children is limited other than in the playground areas. Other than in the playground areas, the auditor understands that the activities are predominantly dog walking, attending the farmers market and having an occasional picnic. This supports the conclusion that the risk is low in the short term, but the uncertainties in such an assessment support the conclusion that remedial action is required in the long term to reduce this uncertainty.*

  The auditor is aware that CoPP has engaged Golder to undertake a Human Health Risk Assessment (HERA) using the existing soil data at the site. The auditor was not provided a copy of the HERA for review, and is unable to comment on its findings.

(c) Range of remedial and management options considered

The auditor agrees that the alternative remedial strategies and technologies identified by EES provide a representative set of options for consideration. The discussion by EES regarding the merits of the various options would have benefited by a high level overview.

Simplified, the options for ongoing management of the site are do nothing, contain (cap) the site, or treat or remove the whole of the contaminated material at the site. With regard to these broad options:

- *"Do nothing" will not meet the objectives and hence it is not appropriate to consider it further.*
- *Capping requires that the site and groundwater be controlled through a Management Plan. This includes areas that may be identified, through further sampling of the surface soil, to not require capping, because higher levels of contamination can remain at depth.*
- *Treatment of the entire waste mass (whether for onsite retention or offsite treatment and disposal) would require very large works, would take a considerable time, and would require careful management to avoid impact on the community.*

Within each of these options there are various sub-options and technology options. The auditor considers that the sub-options and technology options considered by EES are a representative set for consideration.

The on-site treatment options presented consider bioremediation and in-situ thermal treatment. The auditor notes that ex-situ thermal treatment using an on-site thermal desorber was not

considered. This option has been used elsewhere in Australia, but for the reasons outlined in the preceding point this option would rank less favourably than options that allow the site to be retained in its present form. Hence the omission of this treatment technology does not invalidate the decision process.

(d) Definition of the extent of each remedial option

EES does not clearly specify whether the remediation options discussed pertain only to the top 0.5 m of soil (ie the existing surface soils), or to the entire waste volume, which could extend to some 8 mbgl or more. While this introduces a lack of clarity in the discussion of option, the auditor concludes that this is not such that it would change the conclusion that capping the site is the preferred remedial option.

(e) Basis for ranking remedial technologies

The basis upon which EES has assessed the logistical viability of on-site treatment vs off-site treatment and off-site disposal is not clear. For example, there is no indication as to the weighting given to each aspect (for example "onsite treatment – in-situ/ex-situ thermal treatment" has been ranked #2, and "off-site treatment" has been ranked #4, but both have received the same rating for each aspect ("yes" to three aspects, "high to very high" operational costs). The auditor has undertaken a high level assessment to provide an independent assessment to determine whether the EES rankings can be supported.

(f) Future use of the park

In evaluating complete clean up options involving excavation, EES does not emphasise the importance of retaining the park for community purposes and as a heritage feature The auditor notes that the park is an important feature in an area of increasingly high density residential use and is highly valued by the community, and this should be an important aspect in the evaluation of remedial options. The auditor notes that complete clean up (e.g. excavation of the entirety of waste material for treatment of disposal either on site or off site) would be likely to require demolition of the heritage buildings and a major change to the nature of the park, and may lead to a changed future use, which would be undesirable to the community.

(g) Acceptability of capping as a remedial solution

In forming his opinion as to the appropriateness of capping as the preferred remedial option, the auditor also considered the average concentration of the limiting contaminant, BaP, in the soils from surface to 0.5 mbgl depth across the site. The average BaP TEQ concentration in the top 0.5 mbgl of soil is approximately 15 mg/kg (from data provided in EES 2014A). This is in the order of five times the NEPM 2013 HIL-D criteria for BaP TEQ (3 mg/kg). The random nature of the contamination is such that some areas of the site contain much less than the average concentration of BaP, and soil in some areas contains concentrations a magnitude higher.

As the exposure pathway of concern for human health is direct contact to contaminated soils, application of a 0.5 m capping layer would effectively limit exposure of site occupants to contaminants under normal site use scenarios. The cap would be maintained by CoPP through the CMPs (discussed in Section 5.4.4). The auditor considers that the proposed thickness of the cap (0.5 m) is appropriate, noting that the level of contamination is such that if there happened to be a localised breach of the cap (as could conceivably happen) the average concentration of BaP in the surface soils across the site would still be well below the HIL-D criteria (allowing for dilution in the surface soils and the area of contaminated material being only a small part of the total area).

As is noted in the later sections on groundwater contamination, the capping option does result in the risk that if the containing sewers are relined (or replaced), that groundwater levels would

rise and groundwater contamination might migrate from the site, requiring the installation of groundwater interception systems or full clean up of the site. This situation would result in major cost, and is a matter for CoPP to assess whether the business risk is such that full clean up might be preferred over capping.

(h) Plan for future management of the site

The RAP does not clearly articulate the documents that will be used to specify the methods that will be used to manage the human health and environmental hazards that can arise during remedial works at the site, and during the future use of the site. Reference is made to a "CMP" but this is not defined. CMP may refer to a Construction Management Plan, or a Contamination (or Contaminant) Management Plan. For the purposes of this audit the auditor has assumed that CMP refers to a Contamination Management Plan for soil and groundwater, which is to be applied after remediation and which will replace the existing ICMP. The auditor assumes that the management of contamination during remediation of the site will be managed through processes outlined in the RAP, and contractor-specific management plans and/or Job Safety and Environmental Analysis (JSEAs).

(i) Summary of Auditor's findings

The auditor supports EES' conclusion that capping the site can be an acceptable method of contamination management, can reduce the risk posed by the contamination to an acceptable level, and can be the preferred strategy for managing contamination at the site. Key considerations supporting this conclusion are as follows:

- *Contamination extends to a considerable depth, and this can be a source of volatiles that migrate through the soil and pose a risk to persons in buildings on the site. Investigation has shown that this is not occurring and that this is not a factor that drives the selection of the remedial strategy.*
- *Contamination is present at depth, and this will continue to be a source of groundwater contamination. Because groundwater contamination at the site is collected by deep sewers and does not extend beyond the site in other than a small area to the north east of the site, the risk posed by the groundwater contamination is low. In this, the contaminants of concern are ammonia and salinity, and the contamination does not pose a risk to human health. Full clean up or other remedial actions such as intercepting contaminated groundwater would not appear to be warranted in view of the low risk posed by the contamination. Further considerations relating to the risk posed by deep contamination are discussed in Section 5.5.4 and Section 6.*
- *Contamination extends to a considerable depth, and complete clean up involving excavation and treatment or disposal of contaminated soil and groundwater would involve very large works over several years with the potential for adverse impact on the community, can be expected to greatly change the nature of the park, and may change the future use of the park. These factors make full clean up by excavation less preferred if there is an alternative acceptable solution.*
- *Full clean up by in-situ thermal treatment can be less disruptive to the form of the park than excavation, but has not been used previously in Australia and would be technically challenging in view of the heterogeneous and ill-defined nature of the subsurface. It would extend over several years and preclude use of the park where it was being applied. The cost and energy use would be very high.*
- *Capping the site with a clean soil cover prevents exposure of park users to the contamination and allows the park to be used safely, and can be an acceptable method of remediation and management. The concentrations of contamination immediately below the capping layer are moderate, reducing the risk that unacceptable exposure might*

occur if for some reason the capping layer were to be disturbed or not properly maintained. This supports the proposal that the capping thickness be 0.5 m.

Contamination identified in shallow soils (less than 0.5 mbgl) is widespread and appears to be randomly distributed, and difficult to identify and characterise. This supports the conclusion that carrying out additional work to delineate 'hotspots' of contamination and to only carry out remediation of selected areas may have an uncertain outcome and may not result in areas with low contamination being sufficiently well defined to allow them to remain un-remediated. Notwithstanding this uncertainty, the high priority accorded by stakeholders to retaining trees wherever possible would support undertaking such additional work. If such sampling and analysis were to be undertaken, the auditor expects that a high density of sampling would be required to provide the necessary delineation (e.g. 7 m grid, two samples between surface and 0.5 mbgl).

5.4.3 Management of groundwater contamination

EES considered the following options for remediation or management of impacted groundwater at the site:

- No action / monitored natural attenuation (MNA);
- Physical barrier;
- Enhanced bioremediation;
- Air sparging or air stripping;
- Duel phase extraction;
- Advanced oxidation;
- Chemical oxidation; and
- Chemical fixation.

EES' evaluation of the various options was provided in Section 4.5 (Table 8) of the RAP. A relative ranking of each option taking into consideration protection of human health onsite and offsite, capacity to achieve contaminant mass reduction over time; logistical viability, and operational cost was provided in Table 9. Key outcomes were as follows:

- EES concluded that "No action / Monitored Natural Attenuation" was the preferred management option, being protective of human health onsite and offsite, able to achieve contaminant mass reduction over time, logistically viable, and operational costs (i.e. cost of future monitoring) was low.
- Implementation of active remediation groundwater remediation strategies was "impracticable" given the majority of the groundwater is captured by the sewers, there is a low likelihood of use of the groundwater for any beneficial uses due to the reticulated water supply, and the low yield of the Brighton Group aquifer.
- EES concluded the risk posed by the current groundwater conditions to potential receptors is low, based on the surrounding sewer capturing the majority of groundwater originating from the site, the low likelihood of groundwater being extracted for any beneficial use (given the reticulated water supply) and the low yield of the Brighton Group aquifer. However, EES acknowledged that in the area to the north east of the site where the plume of ammonia-contaminated water extends offsite, the potential for extraction of groundwater for irrigation or recreational use cannot be discounted. EES therefore recommended implementation of a Groundwater Quality Management Plan (GQMP) which would provide a mechanism for periodic review of hydrological conditions and contaminant concentrations. EES suggested the GQMP should be developed following

the next round of groundwater sampling, but did not specify when the next round of groundwater sampling should be implemented.

- EES referred to a contingency plan that should be implemented if a series of groundwater requirements (i.e. triggers) are not met. EES did not provide information as to what the contingency plan would entail, but stated the contingency measures will be provided in the GQMP.

Auditor's comments on EES' recommendations

Based on his review of the groundwater data and information provided by EES and Golder, the auditor agrees in principle with EES' conclusion that current groundwater conditions pose a low risk to onsite and offsite receptors and that there is not a strong case for active groundwater remediation. The auditor recommends that potential users of groundwater off site be notified, and that there be ongoing monitoring as recommended by EES. Should hydrogeological conditions change in the future (i.e. contaminant concentrations and/or lateral extent of offsite plume significantly changes), or the sewers currently intercepting groundwater be altered or repaired in a way that might result in contaminated groundwater no longer being captured, then the need for active remediation should be reviewed.

In reaching these conclusions, the auditor notes:

(a) Decision process

The auditor considers that EES' discussion in the RAP as to how the preferred management option for groundwater was derived could be improved. The connection between source, pathway, and potential receptors is not clearly described and, while EES has ranked the various technologies, as for the review of soil remedial technologies, the ranking is subjective without clear discussion on how decisions were made. For example "air sparging or air stripping" has been ranked above "pump and treat", although it is noted that air sparging or stripping does not treat all contaminants and has only a slightly lower operational cost than pump and treat. In addition, EES does not clearly articulate why implementation of active groundwater remediation is considered "impracticable". The reasons provided by EES largely relate to risk (capture of groundwater by sewers and low yield of the Brighton Group aquifer), rather than practicability.

Notwithstanding this concern, the auditor considers that the key consideration is whether the current groundwater conditions can be accepted without active intervention, and, if this is the case, active intervention then can be ranked lower in preference.

(b) Acceptability of current groundwater conditions

In reaching a conclusion as to whether the EES conclusion that the current groundwater conditions are acceptable, and hence ongoing management and monitoring is a viable option, the auditor considered the following key aspects:

- *The use of groundwater on site can be managed through a management plan, and the key matter is whether groundwater contamination poses an unacceptable risk to users off site.*
- *The investigations show that sewers surrounding the site capture contaminated groundwater originating from the site, and that the depth of groundwater is below the level of the sea (Port Phillip Bay) and groundwater will not flow to the Bay. Unless these sewers are repaired in the future, it can be expected that the current flow regime will be maintained and the lateral extent of contamination arising from the site will remain contained within the area bounded by the sewers.*
- *The investigations show that groundwater contamination is contained by the sewers and, other than a localised area to the north east of the site, is contained to the site. The*

limiting contaminant in groundwater offsite to the north east is ammonia, and the lateral extent of the contaminated plume has been well defined in all directions. The measured concentrations of ammonia can affect the use of groundwater for recreation (swimming pool makeup water) or garden watering. In the case of swimming pool make up water, the effect is aesthetic (taste and odour) rather than effects on human health. The recreational water quality guidelines (NHMRC 2008) do not include a health-based criterion. This is an important distinction which EES did not comment on.

- *In the vicinity of the site there are swimming pools and gardens, and water could be used for these purposes. While it can be expected that reticulated water would be used rather than groundwater, the potential to use groundwater rather than reticulated water for these uses needs to be considered. EES identified 18 properties that might be affected by the plume of ammonia-contaminated groundwater. From a review of aerial photography, EES identified two properties within 100 m of the site, one of which appears to be within the plume extent, which appeared to have a pool in the back yard. Up to 27 properties with pools were identified within a 600 m radius of the site. There were no registered groundwater bores within the vicinity of the groundwater plume. The auditor undertook a review of recent (March 2013) imagery and agrees with EES observations.*
- *For adverse effects to occur through swimming pool make up or garden watering, a groundwater bore and pumping mechanism would need to be installed; the adverse effect does not occur through direct contact or inhalation of vapours (the groundwater is too deep). EES concludes that it is unlikely that groundwater will be extracted for such uses. The auditor concurs with this, noting the following factors that support this: the area is a densely populated urban area where reticulated water is readily available, groundwater is deep and has a low yield, access for a drill rig for installation of a bore would be difficult in view of the small property sizes, and the groundwater has uncertain quality in terms of salinity and potential impacts from other sources such as leaking sewers. Notification to residents within the area of impact would further reduce this likelihood.*

5.4.4 Implementation of RAP and community concerns

The Draft Park Plan envisaged carrying out the capping of the site as a single event, which would require removal of all vegetation from the site. CoPP advises that this is the most cost effective remedial approach and that although it will result in complete closure of the park for a year, ultimately the closure duration will be less than if the works were staged. CoPP provided the auditor with a summary of aspects it considered when determining how to approach the remedial works, provided in Appendix M. It was determined that retention of trees was not practicable, given the age and average health of many of the trees, and low likelihood of survival once the surrounding ground was disturbed. Additionally CoPP was concerned that isolating areas surrounding trees (such as collaring to reduce potential exposure) would result in an increased risk to park users, and would require considerable maintenance into the future.

The auditor is satisfied that the proposed approach to capping the entire site as a single event is practicable, and will achieve the ultimate goal of reducing the likelihood of park users being exposed to contamination in soil.

In considering the Draft Park Plan, members of the community have raised concerns regarding the full closure of the park and removal of vegetation, and have queried whether the works could be done in another manner. In response to these concerns, CoPP has advised that it is giving consideration to undertaking further soil testing in treed areas with the objective of establishing whether some of the soil is of a suitable quality that would allow trees to be preserved. CoPP is also giving consideration to whether it could be practical to provide physical barriers to restrict access to areas of contaminated soil, such as fencing or dense planting. The auditor considers that this further evaluation of options is appropriate and further sampling will

result in a better understanding of the distribution of contamination, but cautions that there is uncertainty as to what the outcome of this further work will be.

5.4.5 Ongoing site management (Contaminant Management Plans)

EES has prepared Contaminant Management Plans (CMPs) for the Gasworks park and for the Southport site (EES 2014D and EES 2014E, Appendix I). The CMPs are intended to replace the existing ICMPs for the site, providing strategies to manage health, safety and environmental concerns associated with soil and groundwater contamination at the site. EES advises that the CMPs are intended to be high level, conceptual documents and, as such, task-specific Job Safety Analyses (JSAs) should be completed as required.

The CMPs apply to the site after remediation has been completed (i.e. the site has already been capped with 0.5 m clean soil, and/or acceptable areas of soil (to 0.5 mbgl depth) have been identified). The auditor understands that the site will continue to be managed in accordance with the existing ICMPs until remediation has been completed.

The CMPs outline the following:

- A brief description of soil and groundwater at the site, prior to capping;
- Relevant legislation to be considered;
- Roles and responsibilities for CoPP, contractors and site tenants;
- An assessment of exposure pathways, potential receptors and risk posed to receptors from soil and/or groundwater contamination. EES concluded that the only unacceptable risk was to construction workers conducting subsurface excavations through direct contact with contaminated soils, or inhalation of vapours (this assumes that the site has been capped with 0.5 m clean soil);
- Health and environmental hazards that may result from disturbance of contaminated soil/groundwater and/or exposure of workers to associated vapours, and recommended controls to minimise impacts; and
- Suggested monitoring and reporting (e.g. non-conformances), including handling of community relationships and complaints.

Audit's comments on contaminant management plans

The CMPs provide high-level strategies for managing the potential risks to human health and the environment associated with residual contaminated soil and groundwater at the site. The auditor considers overall the CMPs will provide a useful basis for the development of more detailed, task specific JSEAs. The CMPs should be updated to reflect the final remedial strategy that is adopted, particularly if it is to include areas of contaminated soil that are to be retained on site with barriers such as fencing or dense planting employed to prevent access. Areas such as these will have specific ongoing management requirements that will need to be detailed.

5.5 Reappraisal of risk to beneficial uses of land and groundwater

5.5.1 Introduction

The Interim audit identified 50 (of more than 260) exposure pathway scenarios as 'medium' risk. The remainder of the scenarios were classified as 'low' or 'negligible' risk. The risk matrix is provided in the Interim Audit. The auditor has reviewed these combinations in light of the further soil and groundwater data collected, and the remedial and management measures recommended by EES. In undertaking the review, it was assumed remedial and management

measures will be implemented as described; the auditor's recommendations to this effect are provided in Section 6.

The revised risk matrix, including additional information obtained, proposed management/mitigation measures and residual risk following the application of proposed mitigation and control measures is attached as Appendix K to this report. It should be noted that although all risk profiles (i.e. "negligible", 'low' and 'medium') were reviewed as part of this audit, the risk matrix in Appendix K only includes those scenarios identified in the interim audit as 'medium' risk.

5.5.2 Review of medium risk scenarios on-site

Table 16 below provides a summary of the onsite medium risk scenarios, and Table 17 summarises the offsite medium risk scenarios identified in the Interim Audit, and the revised risk profile based on the implementation of remedial measures discussed in Section 5.4.

Once the site has been capped (with 0.5 m clean material), CMPs finalised and GWMP developed, the auditor's review concludes that six "medium" risk scenarios will remain onsite, and four "medium" risk scenarios will remain offsite.

5.5.3 Status of issues identified in the Interim audit as requiring resolution

The Interim Audit identified five key issues that required resolution, based on the medium risk scenarios that had been identified. These are summarised in Table 18, with a summary of the current status taking into account the additional data collected by EES and proposed remedial measures.

There is also the need to update the ICMPs to address longer-term issues and ensure robustness of the administrative controls; this process is underway and EES has provided updated CMPs.

Table 16 Review of the on-site medium risk scenarios identified in the interim audit

Pathway Description	Beneficial Use (Receptors)	Limiting Contaminants – Interim Audit	Limiting contaminants – Revised	Proposed Risk Treatment / Management Measures	Revised risk	Comments
Land						
Diffusion of gases into onsite buildings (including the residential buildings) arising from onsite contamination (i.e. soil, groundwater, NAPL)	Human health (park users, workers in buildings) Aesthetics	Phenol, ethylbenzene, toluene, xylene NAPL (such as coal tars and oils containing PAHs, BTEX, phenols) VOCs and SVOCs	NA – limiting contaminants attributed to gasworks operations not identified at concentrations above adopted criteria.	Not required	Low	Indoor air quality assessment determined that vapour emissions from gasworks waste/contaminated soil/groundwater were not migrating into buildings at levels of concern.
Diffusion of gases into excavations and subsurface structures arising from onsite contamination (i.e. soil, groundwater, NAPL)	Human health (workers undertaking sub surface works)	VOCs and SVOCs	Naphthalene	Management of site through CMP (updated ICMP).	Medium	Soil assessment identified tar residues and odours at several locations at depth, and elevated concentrations of PAHs (including naphthalene) and TRH in soil. This indicates that vapours can be present in deeper excavations, and workers involved in subsurface work may be exposed to these vapours. The CMPs include measures that are required when undertaking subsurface works to avoid unacceptable exposure. A “medium” risk level has been retained in view of the magnitude of contaminant concentrations.
Direct contact and possible ingestion of contaminated soil	Human health (park users, workers in buildings)	PAHs, TPHs, benzene, cyanide	Total PAHs, BaP, total cyanide, NAPL in soil (viscous tar)	Capping site, updating ICMPs	Low	Proposed capping of site will minimise the likelihood of site users coming into direct contact with soils. Ongoing management of cap required.
	Human health (sub surface workers)	PAHs, TPHs, benzene, cyanide	Total PAHs, BaP, total cyanide, NAPL in soil (viscous tar)	Capping site, updating ICMPs	Medium	Proposed capping of site will reduce likelihood of subsurface workers coming into direct contact with soils. Where excavations extend below 0.5 mbgl, the exposure of workers to contaminants has been ranked as ‘unlikely’, assuming correct precautions (e.g. PPE) are adopted and the CMP is followed. A “medium” risk level has been retained due to the magnitude of contaminant concentrations.
	Aesthetics	Surface waste	Gasworks waste, tars	Capping site	Low	Proposed capping of site will minimise chance of site users coming into direct contact with exposed gasworks waste. Ongoing management of cap required.
Groundwater						
Onsite extraction of contaminated groundwater	Agriculture, parks and gardens	TDS, boron, arsenic, manganese	TDS, fluoride, As, Bo, Co, Fe, Ni	Update ICMPs to CMPs and implement	Low	The CMPs prohibit unauthorised groundwater extraction at the site.

Table 17 Review of the off-site medium risk scenarios identified in the interim audit

Pathway Description	Beneficial Use (Receptors)	Limiting Contaminants – Interim Audit	Limiting contaminants - Revised	Proposed Risk Treatment / Management Measures	Revised risk	Comments
Land						
Diffusion of gases into offsite excavations that has arisen from contaminated groundwater leaving the site	Land (human health (workers undertaking subsurface works)	Ammonia	Ammonia, benzene and TPH C_{10}-C_{36} (three wells)	Ongoing monitoring under a GQMP	Medium	Ammonia has been determined to be the limiting contaminant, with the effect being objectionable odour (aesthetic) rather than an impact on human health. Benzene and TRH are present in some locations (three wells). The depth to groundwater makes it highly unlikely that subsurface works will intersect the groundwater, with the exception of very deep excavations associated with sewer maintenance. A "Deed of Agreement" has been entered into between CoPP, Melbourne Water and South East Water acknowledging the potential for contaminants to be present and requiring the water authorities to notify Council of any proposed works on the sewers. This should reduce the likelihood of sewer workers being exposed to unacceptable contaminant concentrations. Because the concentrations of contaminants in the vicinity of the sewers can be high, this risk has been assigned to be medium.
Diffusion of gases into the sewers that have arisen from contaminated groundwater and NAPL leaving the site.	Land (human health (workers undertaking subsurface works)	Ammonia	Ammonia, benzene and TPH C_{10}-C_{36} (three well)	Ongoing monitoring under a GQMP	Low	Ammonia confirmed as the limiting contaminant, with the effect being objectionable odour rather than effects on human health. Concentrations of benzene and TRH in the immediate vicinity of the site may result in these contaminants being present in gaseous form in the sewers. Normal procedures for working in sewers should be adequate to protect against such vapours. A "Deed of Agreement" has also been entered into between CoPP, Melbourne Water and South East Water acknowledging the potential for such contaminants to enter the sewers and provides operational controls to minimise likelihood of sewer workers being exposed to unacceptable contaminant concentrations; hence risk is low.
Groundwater						
Offsite extraction of contaminated groundwater (shallow and deep) that has arising from onsite contamination.	Groundwater (potable water use)	TDS, ammonia, Ni, Mn, sulphate NAPL such as coal tars and oils containing PAHs, BTEX, phenols	Ammonia, total CN, fluoride, nitrate, sulphate, TDS, Al, As, Mn, Ni, Se, benzene and TPH C_{10}-C_{36} (three wells)	Ongoing monitoring under a GQMP	Low	Risk is considered "low" because: • It is extremely unlikely ("improbable") that groundwater would be extracted and used for drinking water, noting the availability of reticulated water, the restricted access and difficulty of installing wells, low yield of the Brighton Group aquifer, and uncertain quality (e.g. pathogens from

Pathway Description	Beneficial Use (Receptors)	Limiting Contaminants – Interim Audit	Limiting contaminants - Revised	Proposed Risk Treatment / Management Measures	Revised risk	Comments
						leaking sewers). • The lateral extent of plume is localised and has been delineated, and only a small number properties (less than 18) are potentially affected. The risk of use of groundwater can be further reduced by notifying potentially affected residents. • The criterion for the limiting contaminant, ammonia, is based on aesthetic rather than health effects. • Although concentrations of benzene and TPH C_{10}-C_{36} above criteria were detected in two off-site wells in Richardson Street, the GW flow direction makes it unlikely that these contaminants will flow beneath houses. If groundwater contaminated with benzene were to flow beneath houses, it may be in the order 30- 40 µg/L. • The deeper aquifer is unlikely to be contaminated due to upward hydraulic gradient. • A GWMP will be developed for ongoing monitoring of offsite groundwater, which will provide trigger levels for further action if required.
	Groundwater (agriculture, parks and gardens (irrigation))	TDS	TDS, ammonia, fluoride, arsenic, boron, iron,	Ongoing monitoring under a GQMP	Low	TDS (dissolved salts) was reported at concentrations up to 3440 mg/L in the area offsite to the north east, well above the criterion for irrigation (500 mg/L). The potential exists (albeit unlikely) for extraction of groundwater in an area to the northeast of the site for garden watering. There are no restrictions on groundwater extraction in this area, but the use is unlikely, and can be further reduced by notifying affected residents. Although elevated TDS may make the groundwater unsuitable for use for garden watering, because of its effect on some plant species, the effect is likely to be minor.
	Groundwater (primary contact recreation (e.g. filling swimming pools))	Ammonia	Ammonia, arsenic, benzene (three wells), total xylene (one well)	Ongoing monitoring under a GQMP	Low	Risk for ammonia and benzene/xylene has been considered separately, as ammonia guideline is aesthetic based and benzene/xylene guidelines are health based. Ammonia: ”low” as although the ammonia concentrations in groundwater exceed guidelines for primary contact recreation by up to several orders of magnitude offsite to north east of site, The use is unlikely, and the risk relates to odour rather than impacts on human health. Guidelines are based on aesthetic effects, rather than health effects. Benzene/total xylene: it is possible that concentrations of benzene extend beneath a few residential properties at

Pathway Description	Beneficial Use (Receptors)	Limiting Contaminants – Interim Audit	Limiting contaminants - Revised	Proposed Risk Treatment / Management Measures	Revised risk	Comments
						concentrations in the order of 30-40 µg/L (based on results from GW08 and GW37). The concentrations measured in GW38 are higher, but this well is near to the sewer and down gradient from the houses, and does not appear relevant. Concentrations of 30 – 40 µg/L benzene exceed health-based drinking water criteria, and correspond to a lifetime cancer risk level of 3 – 4 in 100,000. Because these contaminants are volatile some would be lost if used for swimming pool make up, the consequence of exposure is minor and, based on the use being unlikely, the risk has been determined to be low.

Table 18 Review of issues identified in the interim audit as requiring resolution

Issue from Interim Audit	Work undertaken by EES to investigate	Findings	Proposed management and/or remedial strategies (this audit)
The extent of contamination in soil and shallow fill, and the performance requirements for capping and control of future activities;	Site capping assessment (soil assessment of near surface (typically less than 2 mbgl) soils)	Shallow soils (0 – 0.5 mbgl) across the site are widely contaminated with visible gasworks waste, and gasworks contaminants (PAHs and BaP the limiting contaminants). EES inferred an attempt had been made to cap areas of the site, but the capping layer is widely contaminated. The distribution of contamination appears random, rather than related to hotspots (though these may exist as well)	Cap majority of the site with 0.5 m clean material. In localised areas where this is not possible 0.3 m clean material underlain by a geotextile warning layer will be used. Potentially conduct further sampling to determine soil quality in areas where there is a desire to retain trees (i.e. to establish whether the top 0.5 mbgl of soil is of suitable quality to retain). Existing bluestone pathway to remain unchanged. Strategy is outlined in the RAP (EES 2014B)
NAPL, particularly its presence and extent on site, and its significance as an ongoing source of vapours and groundwater contamination	Soil assessment of near surface (typically less than 2 mbgl) soils. Groundwater assessment (installation and sampling of new wells on and offsite, and sampling of existing wells) Assessment of indoor air quality assessment.	NAPL in the form of 'viscous tar' was identified in soil at several locations ranging from 0.9 to 2.7 m depth across the site. There was no NAPL, and no evidence (e.g. sheen, concentrations of petroleum hydrocarbons approaching solubility limits) of NAPL identified in groundwater on or offsite. Indoor air quality assessment did not identify concentrations of CoPC at unacceptable levels.	Proposed site capping will minimise potential for site users to come into direct contact with NAPL (tar) in soil. No remedial options necessary for NAPL in groundwater, as NAPL has not been identified. No remedial/management options necessary for indoor air as no unacceptable concentrations in indoor air have been identified.
Vapours, particularly the potential for these to enter buildings	Indoor air quality assessment (two rounds of indoor air quality sampling)	Indoor air quality assessment did not identify any unacceptable concentrations of gasworks related CoPC.	No remedial/management options necessary for indoor air as no unacceptable concentrations in indoor air have been identified.
The migration of dissolved phase groundwater contamination offsite, and the potential for use of this groundwater	Groundwater assessment (installation and sampling of new wells on and offsite, and sampling of existing wells)	Groundwater assessment confirmed offsite plume of groundwater containing elevated concentrations of various contaminants, specifically ammonia as the limiting contaminant, at concentrations precluding offsite beneficial uses of groundwater. Only beneficial uses that may be realised are recreation (extraction of groundwater to fill swimming pools) and irrigation.	Low priority for remedial action as risk is not high and because of the difficultly in taking remedial action (refer Section 4.3.2). Ongoing groundwater monitoring recommended.
The extent to which deeper groundwater might be contaminated and result in groundwater contamination migrating from the site	Installation of three deeper groundwater wells on site, to the base of the Brighton Group Aquifer	Groundwater within deeper wells identified concentrations of various gasworks contaminants (TPH, PAHs, ammonia, TDS, cyanide, various metals) above the adopted criteria. EES concluded that there was an upward gradient from the underlying Older Volcanics Basalt aquifer, and therefore it was unlikely to be impacted by the site. There was no investigation of the OVB aquifer.	Low priority for remedial action because it is unlikely that there will be significant contamination of the deep Older Volcanics Aquifer off site, there is a low likelihood that the groundwater would be used, and the nature of impact is not high.

5.5.4 Conceptual risk model: after remediation

The auditor has reviewed the Conceptual Risk Model (CRM) based on the findings of the risk assessment review, as shown in Figure 5-2 below. The revised risk profile assumes that the remedial and management measures proposed by EES have been implemented as stated, and that the auditor's recommendations, as summarised in Section 6.2, will be implemented.

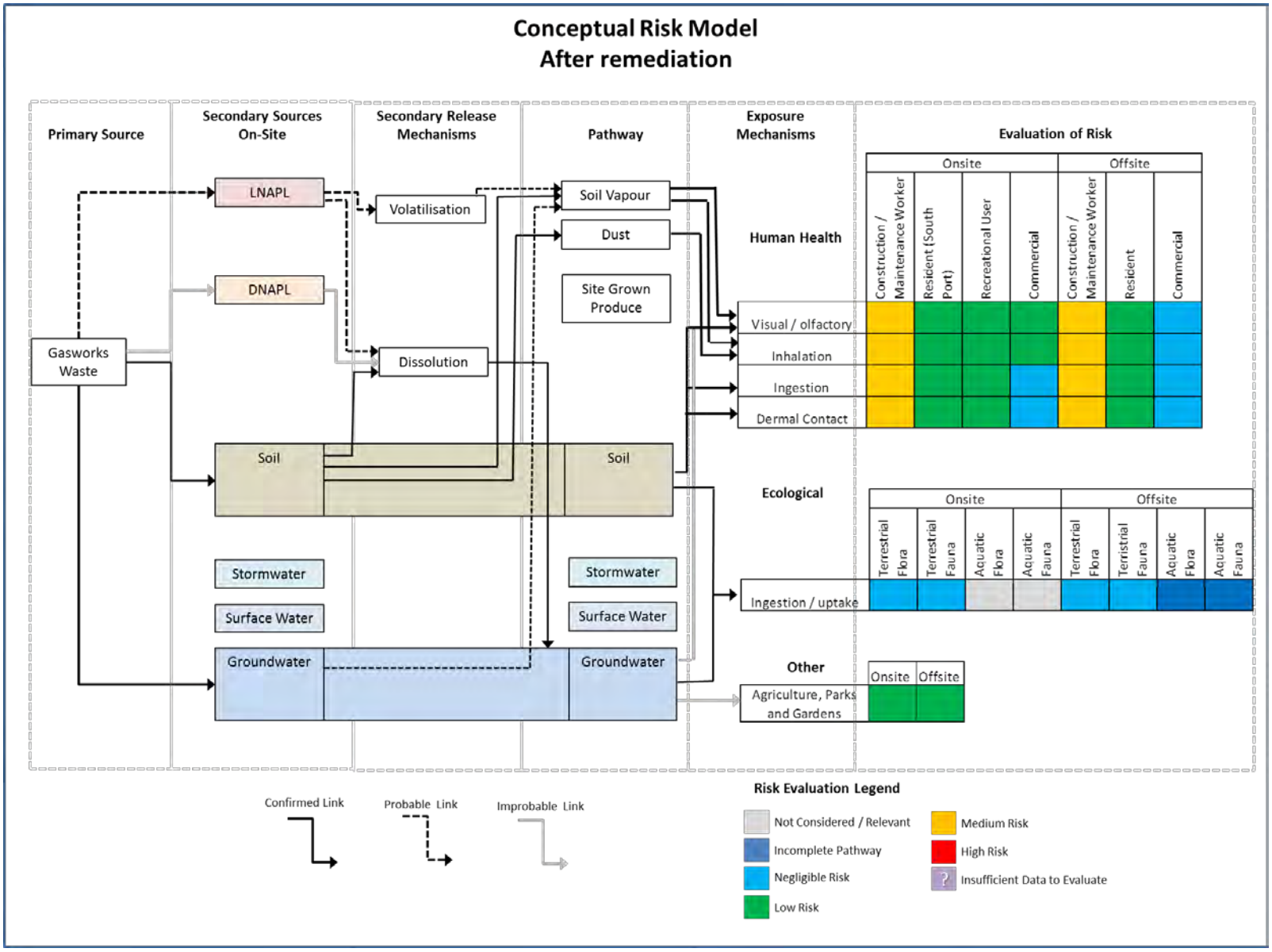
In summary, the post-remediation CRM identifies the following scenarios that remain as a medium risk onsite, and offsite:

- Workers involved in sub-surface works on-site coming into contact with contaminated soil, and/or vapours emitting into excavations. The medium risk in this scenario is driven by the severity of exposure, which is considered to be "major" based on the measured concentrations of BaP and total PAHs. While the presence of a capping layer, and implementation of the CMPs are likely to result in exposure being "unlikely", it still remains possible.
- Workers involved in deep sub-surface works off site coming into contact with contaminated groundwater (e.g. when undertaking sewer works), or being exposed to volatile emissions (e.g. undertaking deep excavations, or possibly within the sewer). This applies to the plume of groundwater contaminated with ammonia extending offsite to the north east, and a smaller area closer to the site (near Richardson Street) of groundwater containing elevated concentrations of benzene, naphthalene and TRH C_6-C_{36}.

As contamination will remain at depth on the site if the capping strategy is adopted, there is the risk that sewerage system works will be carried out that will result in less groundwater ingress, and that containment will no longer be afforded by the sewerage system. If this were to occur, it can be expected that groundwater levels would rise and groundwater contamination might migrate from the site at concentrations that would pose an unacceptable risk to persons off-site. If this situation occurred, it can be expected that groundwater interception systems would need to be installed to contain the contaminated groundwater, or full clean up of the site undertaken. This situation would result in major cost, and it is a matter for CoPP to assess whether the risk is such that full clean up might be preferred over capping.

With respect to installation of a groundwater interception system, if this were to be proposed, it can be expected that this will require the involvement of specialists in this field. Key issues that will require consideration include the configuration of extraction wells (whether vertical or horizontal), the rate of groundwater extraction that will be required to provide effective containment, the ability to dispose of this groundwater direct to sewer in view of the volume, salt load and contaminant concentrations, and the feasibility of treatment and disposal if direct disposal to sewer is not possible in view of the waste that will be generated (eg concentrated brine stream).

Figure 5-2 Conceptual risk model after remediation



6. Conclusions and recommendations

6.1 Conclusions

The auditor has reviewed the soil, soil vapour and groundwater information presented by EES for the site, and has undertaken a review of the risk posed to beneficial users at the site by contamination resulting from historical gasworks operations. The findings of this review are outlined in the following sections.

6.1.1 Soil contamination

The EES investigations reported concentrations of gasworks-related contaminants, particularly PAHs (including BaP), in shallow soils (less than 0.5 mbgl) across the site that exceeded the investigation levels for protection of human health. In its current state, users of the site could come into contact with contaminated soils. While this poses a low risk in the short term (e.g. less than 5 years), the auditor considers that in the longer term it would not be acceptable to retain and use the park in its current form (i.e. without improving the capping). In addition, the revised CMPs should be implemented and reviewed on a regular basis to reduce the potential for workers involved in subsurface works to be exposed to harmful levels of volatile contaminants in the soil (particularly the deeper soil).

The investigations indicate that the soil contamination appears to be randomly distributed and it is difficult to delineate areas where the soil does and does not exceed the acceptance criteria. Because of this, a strategy of seeking to identify areas where the concentration of contamination is lower and remediation is not required has considerable uncertainty. EES concludes that the options that will reliably address the contamination problem are to either fully clean up the site, or to improve the capping to prevent exposure to the contamination.

EES has compared the various options, and concludes that improving the capping is the preferred strategy. EES also makes allowance for further sampling of soils, or installation of physical barriers (such as fences, hard stand pavements or decking), in areas where capping may not be preferred or possible. CoPP has indicated an intention to prepare a Landscape Plan for carrying out necessary improvements to the Park, and the capping strategy proposed by EES is being incorporated in the Plan. A Draft Park Plan has been prepared and released for community consultation, and this has included the provision to cap the site with a minimum of 0.5 m clean fill in the majority of areas, and to manage the Gasworks Park and the Southport site through a CMP.

The auditor has undertaken an independent assessment of options for addressing the soil contamination, and concludes that the remedial strategy recommended by EES is able to achieve an outcome that poses a low risk to beneficial uses for the current use of the site, and can be preferred over other remedial options. In reaching this conclusion, the auditor notes that the proposed strategy can retain the heritage value of the park and minimise overall disruption to the use of the park, while meeting the primary objective of protecting the human health and the environment. In comparison, full clean-up of the park would involve excavations or works to address contamination that is expected to extend to depths greater than 8 m across most of the Park area and may lead to a loss of heritage value (e.g. demolition of historical buildings), be of significantly longer duration, to involve much greater levels of cost, and to have the potential to impact on residential areas in the vicinity of the Park.

However, the capping option does result in the risk that if the containing sewers are relined (or replaced), that groundwater levels would rise and groundwater contamination might migrate from the site, requiring the installation of groundwater interception systems or full clean up of the site. This situation would result in major cost, and it is a matter for CoPP to assess whether the risk is such that full clean up might be preferred over capping.

In addition to protecting the health of persons who use the park, capping can improve the longer term ecological status of the site. Experience has shown that it is possible to establish suitable plants at the site (although this has not been without some trial and error), and it can be expected that provision of an additional 0.5 m of suitable soil as capping material will improve the ability to sustain suitable plantings.

The auditor notes that in preparation of the RAP and Draft Park Plan, EES and CoPP have considered whether existing trees can be retained, and a more limited program of remediation undertaken in a staged approach to avoid closure of the whole of the Park during the remedial works. This work has involved CoPP's Landscape Architect and an aborist to advise on the possibility of retention of certain trees. The outcome of these considerations was that it is proposed to undertake the works in a single program that involves removal of all existing trees, with some of the replacement vegetation involving mature plants and different species more suited to the nature of the park. A factor in reaching this conclusion was that a significant proportion of the existing trees have limited life and will require replacement in due course in any event, and that attempting to avoid capping and instead provide other measures of preventing exposure are unlikely to be satisfactory in the longer term and may compromise the long term reliability of the capping approach.

CoPP has consulted with the community to determine their views; this has indicated that the community (in particular the users of the park) accord a high priority to adopting a remedial strategy that will provide for retention of trees and will minimise disruption to the use of the park. In response to these concerns, CoPP is exploring alternative options for the site. These are detailed below, with the auditor's opinion on each option:

1. Do nothing (or delay works indefinitely).

This is not considered an acceptable option, because the risk posed to users of the park by the shallow soil contamination in the long term will exceed the acceptable level.

2. Undertake capping across the site in accordance with the Draft Park Plan.

This is considered an acceptable approach, subject to recommendations outlined below.

3. Halt the Draft Park Plan, undertake further testing within treed areas to assess whether any areas can be excluded from capping (and hence retain the trees in these areas). Clean up as necessary.

This is considered an acceptable approach, but the outcome is uncertain as sampling may or may not indicate there are areas of soil of acceptable quality. Because of the high level of variability in the observed concentrations of contaminants , a large number of samples on a close grid basis will be required to provide certainty that the concentration of contaminants accord with the requirements for safe long term use of the park. Further sampling may result in the following broad outcomes:

- *Soil concentrations of CoPC are acceptable in some areas, in which case these areas would not require capping. The maintenance measures specified in the CMPs would still apply to these areas, as soils at a greater depth than 0.5 mbgl are likely to be contaminated.*
- *Concentrations of CoPCs are slightly elevated in treed areas. Under this scenario measures to reduce access may be acceptable, such as increased planting or a small fence that would make it unlikely that young children (less than 6 years old) would access the treed areas. The CMPs would need to be updated to reflect management requirements in these areas.*
- *Concentrations of CoPCs are the same, or higher than previously identified. In this instance the treed area would need to be capped, or measures taken to prevent access to*

the areas. As above, the CMPs would need to be updated to reflect management requirements.

For each of these options, there is a requirement for the RAP to be updated and finalised to reflect the course of action adopted.

6.1.2 Soil vapour

Based on an indoor air quality assessment, EES concluded the risk posed to occupants of the buildings on site (Southport residents and users of various buildings on Gasworks Park) through exposure to volatile contaminants arising from soil and/or groundwater contamination is low. Concentrations of several chemicals of potential concern were detected but, with the exception of benzene, all were below the acceptance criteria. EES attributed the presence of benzene and other chemicals to other activities being carried out in the buildings, rather than being caused by sub-surface gasworks-related contamination.

The auditor concurs with EES' assessment, and concludes that the sub-surface contamination poses a low risk to occupants of buildings that are currently present at the site. If new buildings were to be constructed further investigation would be required to confirm that volatile ingress will not be a problem.

The potential for vapours to pose a risk to outdoor users of the site has been considered but, because of the dilution that will occur in the air, it is concluded that the level of this risk is very low.

6.1.3 Groundwater contamination

EES' investigations found that groundwater beneath the site is contaminated with a range of gasworks related contaminants (TPH, BTEX, PAHs, various metals, ammonia, cyanide) at concentrations that effectively preclude the beneficial uses specified for the groundwater at the site (Segment A2). EES has considered the risk posed by these contaminants, and concludes:

- The use of groundwater on site will be managed through a Groundwater Management Plan, and this will not permit use of groundwater on site. Because of this, groundwater contamination at the site poses a low risk.
- The flow of groundwater flow from the site is intercepted by deep sewers that run beneath roadways surrounding the site, in particular sewers that run along the north west, south west and south east boundaries of the site.
- There is an area to the north east of the site where groundwater from the site migrates beyond the site boundary and under some 18 residences, prior to being intercepted by the deep sewer that runs along the eastern boundary of the site. The contamination involves a variety of contaminants, including ammonia, cyanide, TDS, benzene, total xylene, and TRH C_6-C_{36} that can exceed the investigation levels for beneficial uses (maintenance of ecosystems, drinking water, irrigation, stock watering, industrial water use and primary contact recreation). Of these contaminants, ammonia is the most significant for the uses that are relevant in the area.

Although the ammonia concentrations offsite to the north east are several orders of magnitude above the investigations levels, the risk posed by ammonia to the beneficial uses of irrigation (garden watering), drinking water, and primary contact recreation (e.g. for swimming pools) has been determined to be low. In assigning this risk, the auditor notes that, although the concentrations are high relative to the investigation levels, the nature of the effect of the contamination is not severe (taste and odour in the case of swimming pool make up, excessive leafy growth in the case of garden watering, and taste and odour in the case of drinking water), there is a low likelihood of extraction given the reticulated water supply and the difficulty of

installing extraction wells (an observation supported by absence of groundwater wells identified in the area where contamination is present).

Concentrations of benzene observed in three offsite wells to the north east also exceed investigation levels; based on the level of exceedance and likelihood of use, the risk has been determined to be low.

The risk associated with off-site groundwater contamination can be further reduced by notifying potentially affected residents of the restrictions on use of groundwater. Consideration could also be given to assigning a Groundwater Restricted Use Zone (GRQUZ) for the area, although the level of risk does not appear to warrant this.

6.1.4 Requirements for verification of works

At the time of completion of this audit, there will be the requirement for further sampling and assessment of soil contamination (if this option is selected), the Remediation Action Plan to be finalised, remedial works carried out, and Contaminant Management Plans to be finalised reflecting the final condition of the land. The Interim Audit envisaged that there would be a further audit to confirm that the final condition of the land after remedial works had been carried out had resulted in an acceptable level of risk. An alternative not involving a further audit would be to have an auditor verify that the works had been carried out and the intent of the recommendations had been met. The auditor considers that either option can achieve an acceptable outcome, and has included the requirement for verification in his recommendations. This is a matter for EPA to consider, and EPA may require that a further audit be undertaken.

CoPP queried whether the requirement for verification of the remedial works could be avoided if, for example, the RAP were to include a specification for the works that had been verified by an auditor. While this may provide for an acceptable outcome, there could well be variations in the works from that specified, and verification of the final works would provide more certainty and more reliable documentation on the “as built” final form of the Park. Because of this, the auditor has recommended that there be verification of the final form of the park. This is also a matter for EPA to consider, and EPA may not require verification of the remedial works.

6.2 Recommendations

The auditor’s recommendations are listed in Table 19. These recommendations assume that the site will be remediated in accordance with the Draft Park Plan (i.e. the majority of the site will be capped with a minimum of 0.5 m clean soil, and that further soil testing may be undertaken in treed areas), the Contaminant Management Plans will be implemented, and a Groundwater Quality Management Plan will be developed and implemented.

Table 19 Auditor recommendations

Recommendation		Importance	Required Timing
1.	That CoPP consider the risk that sewer works might be carried out at some time in the future reducing groundwater ingress, and that this would then necessitate groundwater interception or full clean up of the site, and whether this risk is such that full clean up is the preferred strategy.	High	Prior to finalisation of the RAP
2.	That, if determined by CoPP as the preferred option, further soil testing be undertaken in areas where CoPP wishes to retain trees, or otherwise avoid capping. It is expected that a high density of sampling locations will be required (e.g. 7 m grid), with a minimum of two samples analysed between surface and 0.5 mbgl at each location. The scope of work for this soil testing should be reviewed and verified by an environmental auditor prior to implementation.	High	Prior to revision and finalisation of the RAP

Recommendation		Importance	Required Timing
3.	That the results of any further sampling (if undertaken) be documented in a report. This report may be a standalone document, which should outline in detail the works undertaken, analytical results, and conclusions as to soil quality in areas investigated). The report should be reviewed and verified by an environmental auditor.	High	Prior to revision and finalisation of the RAP.
4.	That when agreement has been reached with stakeholders (including EPA and DTF) on the remedial strategy, the RAP be revised to provide more detail on the works proposed (including any further sampling to be undertaken, as above) and address the issues noted in this audit report, and that the RAP be reviewed and verified by an auditor prior to its implementation.	High	Prior to commencement of site capping.
5.	That the remedial actions proposed in the RAP be implemented and verified by an Environmental Auditor.	High	To be determined by CoPP.
6.	That the CMPs be updated and finalised to reflect the final remedial strategy adopted, and to identify any areas where contamination may remain at the surface with restricted access (i.e. fenced areas). The updated CMPs should be verified by an Environmental Auditor.	High	Prior to commencement of site capping.
7.	That a report be prepared detailing the remedial works that have been undertaken, including the results of validation sampling (imported fill material and areas of soil that may be retained at surface), soil tracking documentation, soil balance (cut/fill) modelling, pre- and post- capping topographical survey to show a minimum 0.5 m capping has been achieved.	High	Following remediation.
8.	That a final Groundwater Quality Management Plan (GQMP) to provide for ongoing management of groundwater contamination at the site be prepared, and verified by an Environmental Auditor. This GQMP should include the requirements for ongoing monitoring of groundwater, trend analysis, trigger values for assessing monitoring results, contingency plans should the trigger values be exceeded, and a contingency plan should it be proposed that the sewers be refurbished to prevent ingress of groundwater.	High	This should be drafted prior to commencement of site capping, and finalised after agreement on the controls to be placed on groundwater use.
9.	That the requirement for and nature of institutional controls on the use of groundwater that is potentially affected by contamination arising from the site be determined in conjunction with EPA, and implemented. This might include, for example, notifying potentially affected residents of the limitations on groundwater use, or the implementation of a Groundwater Quality Restricted Use Zone (perhaps through extension of existing GQRUZs in the area, such as at 83-85 Danks Street, or the Former Gasworks Meter Shop Site at the corner of Pickles and Graham Streets).	Medium	In conjunction with the preparation of a GQMP.
10.	That the currency of the “Deed of Agreement” between CoPP, South East Water and Melbourne water be reviewed for currency and to ensure that adequate management and notification measures are in place to protect subsurface and sewer workers, and to advise on planning relating to sewer refurbishment.	Medium	Ongoing
11.	That the CMPs be implemented.	High	Upon completion of the remedial works. Ongoing.
12.	That the GQMP be implemented.	Medium	Ongoing.
13.	That consultation with stakeholders be undertaken in accordance with CoPP’s community consultation plan, so that the views of stakeholders can be considered when finalising and implementing the various Plans.	High	Ongoing

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Figures

Figure 1 Site location

Figure 2 Site layout

Figure 3 Soil vapour sampling locations

Figure 4 Soil bore locations

Figure 5 Soil – PAH and BaP exceedances (0 to 0.5 mbgl)

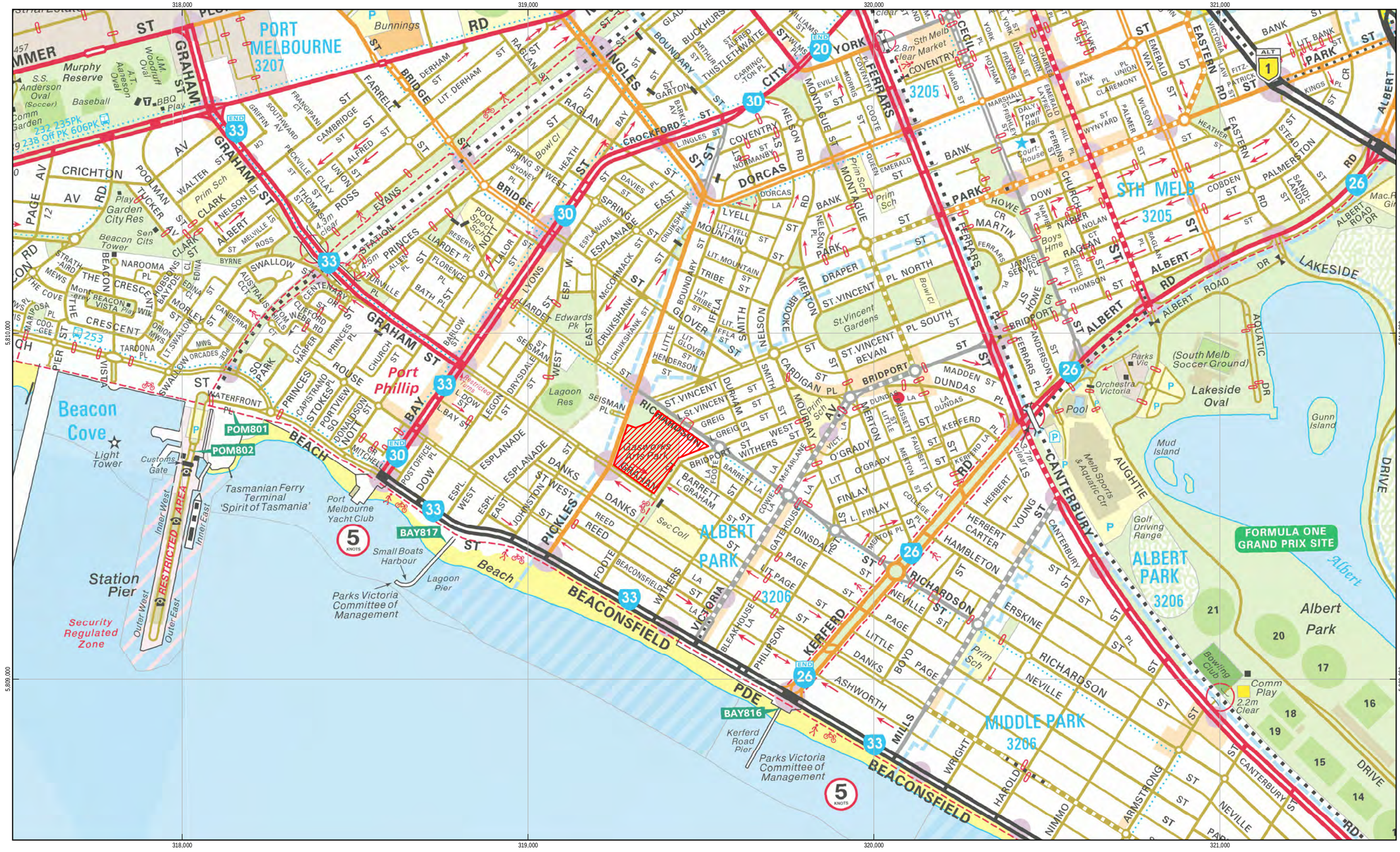
Figure 6 Groundwater monitoring well locations

Figure 7 Groundwater contours (April 2011)

Figure 8 Groundwater contours (July 2013)

Figure 9 Groundwater – ammonia concentrations (April 2011)

Figure 10 Groundwater – TDS (April 2011)



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Site Location

City of Port Phillip
Section 53V Environmental Audit
Gasworks Site, Albert Park

Job Number 31-26548
Revision 1
Date 11 Apr 2014

Site Location

Figure 1

G:\31\26548\GIS\Maps\Deliverables\3126548_001_Site_Locality_A3L_FINAL.mxd

Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); MelWay Ed. 39, AUSWAY, 2011. Created by: bcoughlan

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Note: Information used to create this figure has been sourced from *Environmental Earth Sciences, 2014, 'Site Capping Investigation at Former South Melbourne Gasworks', Version 3, EES, March 2014.*

1:1,200 at Paper Size A3 (Main Map)
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Metres
1:500 at Paper Size A3 (Inset Map)
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND
- Site Boundary
- Building
- Shed

City of Port Phillip
Section 53V Environmental Audit
Gasworks Site, Albert Park

Job Number 31-26548
Revision 1
Date 11 Apr 2014

Site Layout

Figure 2

G:\31\26548\GIS\Maps\Deliverables\3126548_002_Site_Layout_A3L_FINAL.mxd

Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2014); Site Buildings, CoPP, 02/2011 (received March 2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

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Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2012, 'Indoor Ambient Air Vapour Investigation at Former South Melbourne Gasworks', Version 2, EES, November 2012.*

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Metres

1:500 at Paper Size A3 (Inset Map)

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Soil Vapour Bore

City of Port Philip
Section 53V Environmental Audit
Gasworks Site, Albert Park

Job Number	31-26548
Revision	2
Date	01 Sep 2014

EES Soil Vapour Sampling Locations

Figure 3

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Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Soil Vapour Bores, EES, 10/2012 (digitised by GHD, 04/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

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Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2014. 'Site Capping Investigation at Former South Melbourne Gasworks'; Version 3, EES, March 2014.*

1:1,200 at Paper Size A3

0 12 24 36 48

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Borehole Sampling Location
- Test Pit Sampling Location

City of Port Philip
Section 53V Environmental Audit
Gasworks Site, Albert Park

Job Number	31-26548
Revision	2
Date	01 Sep 2014

EES Soil Sampling Locations

Figure 4

G:\31\26548\GIS\Maps\Deliverables\3126548_004_Soil_Bore_Locations_A3L_FINAL.mxd

Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Soil Sampling Locations, EES, 09/2011 (digitised by GHD, 04/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

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Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2014, 'Site Capping Investigation at Former South Melbourne Gasworks', Version 3, EES, March 2014.*

1:1,200 at Paper Size A3

0 12 24 36 48

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Borehole - Exceeded Criteria
- Test Pit - Exceeded Criteria
- Borehole - No Exceedance
- Test Pit - No Exceedance

HIL A & C - BaP (TEQ)	3mg/kg
HIL A & C - PAH	300mg/kg

Exceeds NEPM (2013) HIL A and HIL C

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Soil PAH and BaP Exceedances (0.00m - 0.50m)

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Figure 5

G:\31\26548\GIS\Maps\Deliverables\3126548_005_Soil_PAH_&_BaP_Exceedances_A3L_FINAL.mxd

Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Soil Sampling Locations, EES, 09/2011 (digitised by GHD, 04/04/2014); Soil Exceedance Tables, EES, 03/2014; CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

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Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2013, 'April 2011 Groundwater Investigations at Former South Melbourne Gasworks', Version 3, EES, September 2013.*

1:1,600 at Paper Size A3

0 16 32 48 64

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Groundwater Well - Installed Pre-EES Investigation
- Groundwater Well - Installed During EES Investigation
- Groundwater Well (Deep) - Installed During EES Investigation

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Job Number	31-26548
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Date	11 Apr 2014

Groundwater Monitoring Well Locations

Figure 6

G:\31\26548\GIS\Maps\Deliverables\3126548_006_Groundwater_Monitoring_Well_Locations_A3L_FINAL.mxd

Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Groundwater Monitoring Wells, EES, 08/2010 (digitised by GHD, 04/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

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Note: EES indicated that deeper groundwater well levels (red) have been corrected for salinity effects, however these corrected levels were not used during contour generation. Freshwater heads were calculated for the measured head, measured salinity and measured temperature.

Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2013, 'April 2011 Groundwater Investigations at Former South Melbourne Gasworks', Version 3, EES, September 2013.*

1:1,600 at Paper Size A3

0 16 32 48 64

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Sewer above water table
- Sewer below water table
- Groundwater Contours - April 2011
- Inferred Groundwater Flow Direction
- Groundwater Well - Installed Pre-EES Investigation
- Groundwater Well - Installed During EES Investigation
- Groundwater Well (Deep) - Installed During EES Investigation

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EES Groundwater Contours - April 2011

Figure 7

G:\31\26548\GIS\Maps\Deliverables\3126548_007_Groundwater_Contours_April_2011_A3L_FINAL.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Groundwater Monitoring Wells, EES, 08/2010 (digitised by GHD, 04/04/2014); Groundwater Contours and Inferred Flow Direction (April 2011), EES, 09/2013 (digitised by GHD, 08/04/2014); Sewer Infrastructure, EES, 09/2013 (digitised by GHD, 08/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

Note: EES indicated that deeper groundwater well levels (red) have been corrected for salinity effects, however these corrected levels were not used during contour generation. Freshwater heads were calculated for the measured head, measured salinity and measured temperature.

Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2013, 'April 2011 Groundwater Investigations at Former South Melbourne Gasworks', Version 3, EES, September 2013* and *Environmental Earth Sciences, 2014, 'Supplementary Groundwater Investigation at Former South Melbourne Gasworks', Version 2, EES, January 2014.*

1:1,600 at Paper Size A3

0 16 32 48 64

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Sewer above water table
- Sewer below water table
- Groundwater Contour
- Inferred Groundwater Flow Direction
- Groundwater Well - Installed Pre-EES Investigation
- Groundwater Well - Installed During EES Investigation
- Groundwater Well (Deep) - Installed During EES Investigation

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EES Groundwater Contours - July 2013

Figure 8

G:\31\26548\GIS\Maps\Deliverables\3126548_008_Groundwater_Contours_July_2013_A3L_FINAL.mxd

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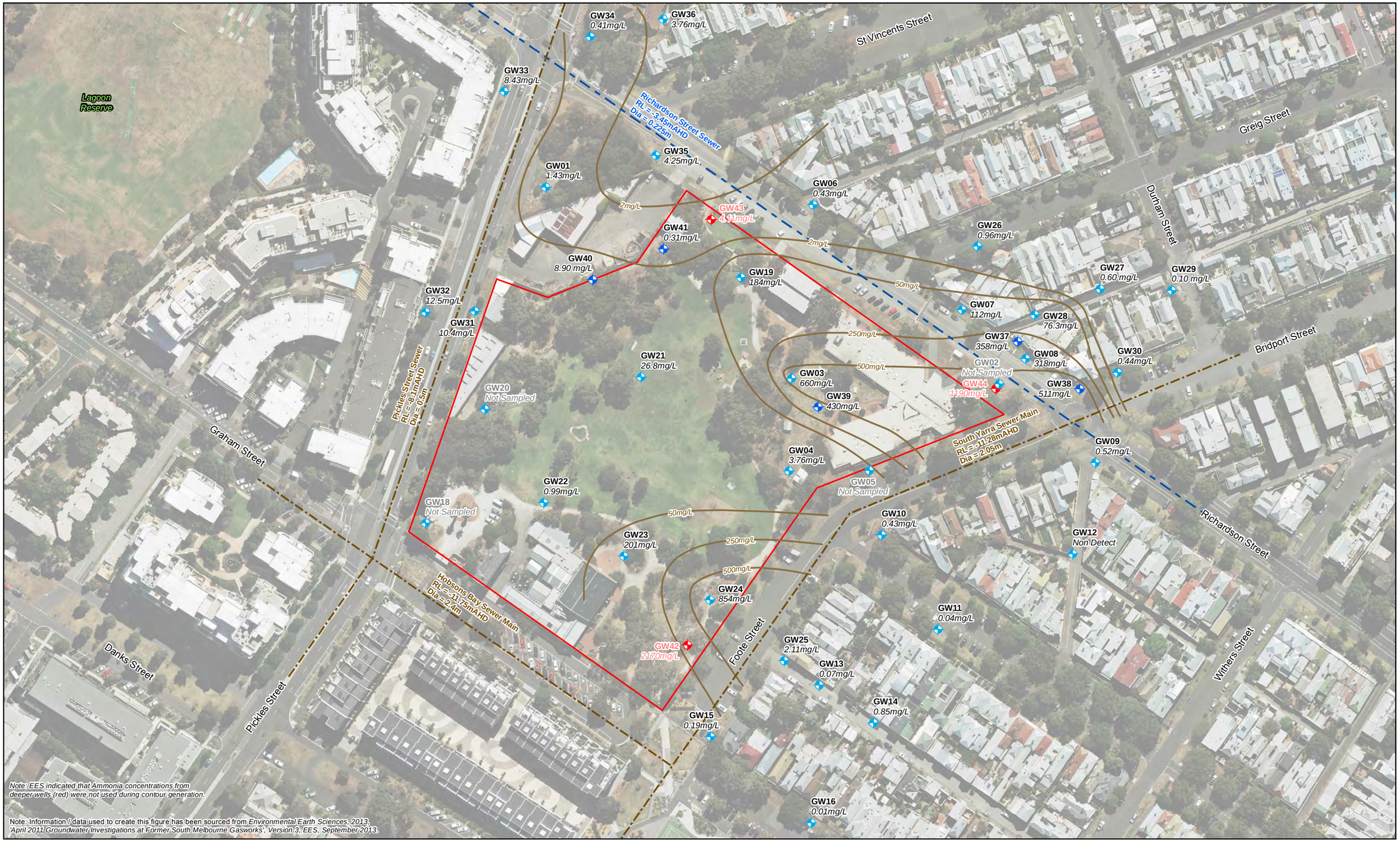
Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Groundwater Monitoring Wells, EES, 08/2010 (digitised by GHD, 04/04/2014); Groundwater Contours and Inferred Flow Direction (July 2013), EES, 01/2014 (digitised by GHD, 10/04/2014); Sewer Infrastructure, EES, 09/2013 (digitised by GHD, 08/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan



1:1,600 at Paper Size A3

0 16 32 48 64

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Sewer above water table
- Sewer below water table
- Ammonia (NH3) Contours - April 2011
- Groundwater Well - Installed Pre-EES Investigation
- Groundwater Well - Installed During EES Investigation
- Groundwater Well (Deep) - Installed During EES Investigation

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EES Groundwater Ammonia (NH3) Contours - April 2011

Job Number	31-26548
Revision	3
Date	01 Sep 2014

Figure 9

G:\31\26548\GIS\Maps\Deliverables\3126548_009_NH3_Contours_April_2011_A3L_FINAL.mxd

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Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Groundwater Monitoring Wells, EES, 08/2010 (digitised by GHD, 04/04/2014); Ammonia Contours (April 2011), EES, 08/2011 (digitised by GHD, 10/04/2014); Sewer Infrastructure, EES, 09/2013 (digitised by GHD, 08/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

Note: EES indicated that Total Dissolved Solid concentrations from deeper wells (red) were not used during contour generation.

Note: Information / data used to create this figure has been sourced from *Environmental Earth Sciences, 2013, 'April 2011 Groundwater Investigations at Former South Melbourne Gasworks', Version 3, EES, September 2013.*

1:1,600 at Paper Size A3

0 16 32 48 64

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Site Boundary
- Sewer above water table
- Sewer below water table
- Total Dissolved Solid (TDS) Contours - April 2011
- Groundwater Well - Installed Pre-EES Investigation
- Groundwater Well - Installed During EES Investigation
- Groundwater Well (Deep) - Installed During EES Investigation

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Gasworks Site, Albert Park

EES Groundwater Total Dissolved Solids (TDS) - April 2011

Job Number	31-26548
Revision	3
Date	01 Sep 2014

Figure 10

G:\31\26548\GIS\Maps\Deliverables\3126548_010_TDS_Contours_April_2011_A3L_FINAL.mxd

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Data source: Site Boundary, GHD, 2014 (survey information received from CoPP March 2013); Groundwater Monitoring Wells, EES, 08/2010 (digitised by GHD, 04/04/2014); Total Dissolved Solid Contours (April 2011), EES, 08/2011 (digitised by GHD, 10/04/2014); Sewer Infrastructure, EES, 09/2013 (digitised by GHD, 08/04/2014); CIP Autumn 2013 Imagery, CoPP, 19/03/2013. Created by: bcoughlan

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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