Ref:01140

NOVARTIS

NOVARTIS PHARMACEUTICAL, WIMBLEHURST ROAD, HORSHAM, SUSSEX

LAND QUALITY INTERIM REPORT

NOVEMBER 2016

6 Earls Court
Earls Gate Business Park
Roseland Hall
Grangemouth
FK3 8ZE
Tel: +44 (0)1324 474816
Email: info@kdc.co.uk

www.kdc.co.uk

Revision History

Date	Rev. No.	Detailed Description of Change	Ref. Section
31.10.16	V1	First issue	
30.11.16	V2	Second issue – DQRA write up	

Ref: 01140

NOVARTIS

NOVARTIS PHARMACEUTICAL, WIMBLEHURST ROAD, HORSHAM, SUSSEX

LAND QUALITY INTERIM REPORT

CONTENTS

DECOMMISSIONING DEMOLITION REMEDIATION

FIGURES

APPENDICES

File Name: 15606-REP-002.docx
Version: d1

Prepared By:	Liz Copland / Rebecca McCuaig	Date:	29 November 2016	Initials:	LC / RM
Checked By:	Michelle McIntosh	Date:	30 November 2016	Initials:	MM
Verified By:	Christopher Sandground	Date:	30 November 2016	Initials:	CS

EXECUTIVE SUMARY

KDC Contractors Ltd (KDC) was instructed by Novartis Pharmaceutical (Novartis) to undertake a Land Quality Assessment at their Wimblehurst Road site, Horsham. This work was requested to provide a summary of the land condition to identify any potential pollutant risks to future site users and the water environment, and address any remedial concerns, prior to the sale of the land.

Initial Site Investigation and Assessment

The initial site investigation included the installation of boreholes, the excavation of trial pits and the collection of soil and water samples. A generic quantitative risk assessment (GQRA) was undertaken using soil and groundwater data collected at the site to quantify risks to both human health and the water environment. The human health risk assessment assessed the risk to future site users for both commercial and residential end use scenarios. The water environment risk assessment determined risks to surface water and groundwater as a resource. Following the GQRA, a remedial action programme was devised.

Remedial Programme

Works included delineation and off-site removal of contaminated soils in areas where risks has been identified; further investigation in areas of the site that were previously restricted e.g. areas close to the railway, service runs, areas exposed following building demolition; pumping and offsite disposal of groundwater from contaminated trial pits; and further sampling in the near surface soils, which would confirm potential risks to future site users. A detailed quantitative risk assessment (DQRA) was also carried out to determine whether soil sources could pose a risk to the water environment, and whether contaminated groundwater onsite could mitigate off-site, and cause harm to nearby surface water receptors.

Data from the additional investigation and remedial digs was screened against the assessment criteria. Failures of the human health criteria were identified that required either further delineation or additional detailed assessment. The groundwater assessment concluded that, following the removal of the contaminated soils and groundwater, there was a low risk to the wider environment.

DQRA Delineation and Validation

A detailed quantitative risk assessment was undertaken to assess whether residual contamination at depth would cause a significant risk to the receptor. Where a risk still existed, further delineation was carried out, the identified soils were excavated and removed off-site and the excavations validated.

Final Site Condition

All waste soil was disposed of off-site in accordance with Waste (England and Wales) (Amendment) Regulations 2012. All excavations were backfilled with either suitably validated material or imported infill, and the site levels reinstated.

Residual Risks

Residual risks persist on the site in the form of trace asbestos fibres in near surface soils, and elevated inorganics and PAHs concentrations, which may cause harm to a residential end use. The addition of a suitable cap to the site would mitigate exposure and reduce potential for harm. Should the site levels change as part of any development, the risk assessment should be revisited.

1. INTRODUCTION

1.1 Brief

KDC Contractors Ltd (KDC) was instructed by Novartis Pharmaceutical (Novartis) to undertake a Land Quality Assessment at their Wimblehurst Road site, Horsham.

A first phase of intrusive investigation, localised remediation works and data assessment was undertaken and recommendations were made in KDC's Phase 2 Environmental Investigation Report (Ref: KDC 01140, July 2016). These recommendations outlined additional further intrusive works, soil and groundwater sampling, detailed quantitative risk assessment (DQRA), and contaminant source removal of certain areas by KDC at the site. These recommendations and works have been reviewed, summarised and assessed, in this current interim report, to determine if any further remedial actions may be necessary prior to the site redevelopment.

1.2 Background

The site was utilised for pharmaceutical Research & Development until its closure in 2014. Demolition of the majority of the site buildings commenced in April 2015 and was completed in June 2016. The programme of demolition included the demolition of all of the buildings, with the exception of Building 3, Building 36. The works also included the removal of the related building slabs and foundations to a depth of 1m.

KDC understands that Novartis wish to sell the site in a condition where no further remedial works are required to the purchaser. To allow this to be undertaken, a phased approach of investigation and remediation is necessary. It is understood that the site within the demolition scope is to be sold and redeveloped for mixed residential and commercial/light industrial use. Limited information is available at this date regarding the exact areas of the site to be developed for each different land use.

1.3 Scope of Works

The additional assessment described in this current report and the and remediation works undertaken to date will either mitigate confirmed risks identified in the Phase 2 Environmental Investigation Report, or provide greater certainty in the site conditions, thereby limiting risk.

The scope of this current report includes:

- A summary of further remedial and investigation works undertaken since the Phase 2 Report was issued in July 2016.
- Generation of Level 2 soil criteria to be protective of groundwater resource potential.
- Generation of Level 3 soil criteria to be protective of surface water receptors.
- Generation of Level 3 groundwater criteria to be protective of surface water receptors.
- Further Human Health Risk Assessment – assessment of additional soil data against Generic Assessment Criteria (GAC) for a site.
- Assessment of soil and groundwater data against Water Environment DQRA Site Specific Action Criteria (SSAC).
- Detailed quantitative risk assessment of risks to future site users and statistical analysis for planning use scenario.
- Details of additional remedial excavation.
- Summary of residual pollutant linkages and residual risks.

1.4 Disclaimer

This report has been prepared for the sole and exclusive use of Novartis and may be relied upon by Novartis only, to whom we owe a duty of care. Our report must not be passed for information, or for any other purpose, to any third party without our prior written consent. Such consent shall not entitle the third party to place any reliance on the report and shall not confer or purport to confer on any third party any benefit or right pursuant to the Contracts (Rights of Third Parties) Act 1999 or otherwise. We do not accept any liability to any third parties unless we have, in the form of a reliance letter, or collateral warranty, expressly accepted that we owe a duty of care to such third parties.

Any site investigation provides an assessment of the site conditions in certain locations from which conditions of the site, as a whole, are interpreted. Therefore, on-site conditions or contamination (including contamination which has migrated or is migrating) may exist which have not been disclosed from the information provided to KDC by third parties or encountered during the KDC site investigation. Additionally, the passage of time, natural occurrences and future activities may alter discovered conditions.

2. SUMMARY OF PREVIOUS WORKS

2.1 Preliminary Investigations

KDC previously completed a Phase 1 Desk Study, 'Historical Land Quality Investigations Data Review and Preliminary Risk Assessment' report (Ref: KDC 01140, July 2016). KDC then undertook an initial phase of ground investigation, remediation and assessment which was completed in June 2016. This included the excavation of 67 trial pits; installation of seven boreholes; localised excavation and validation of gross hydrocarbons; soil, gas and groundwater sampling; and generic quantitative risk assessments to determine risk to future site users (residential and commercial, water environment and property).

KDC reported their findings and recommendations for further intrusive works in their report, Phase 2 Environmental Investigation Report (Ref: KDC 01140, July 2016). The following recommendations were made:

- Soil sampling in near surface soils at trial pits TP3, 18, 24, 29, 33, 39, 42 and 46; CP4; Building 42; and Former diesel tank, and TP28, 29 and 30 for potential asbestos containing material (ACM)

- Further trial pitting to assess the potential contamination where strong fuel odours have been noted in storm drains near the eastern railway line

- A third round of groundwater sampling at all boreholes

- Level 2 soil detailed quantitative risk assessment of soils in areas where leachate samples have indicated a potential risk to the groundwater as a resource

- Level 3 soils and groundwater detailed quantitative risk assessment in areas where groundwater and leachate samples have indicated a potential risk to surface waters. If a risk is still concluded after this Level 3 DQRA, this process will also generate 'clean-up' soil and groundwater criteria to assist in validation verification following source material removal

- Localised dig out in areas where a potential risk to future site users exists from an inhalation pathway from VOCs or from inhalation driven TPH additive risk. The assessment carried out to date has developed appropriate verification criteria. Localised dewatering of excavations should also be carried out in conjunction, particularly at trial pits TP28, TP30, TP46 and TP30

- Given the historical nature of the site and from evidence of contamination observed during local excavations, consideration should be given for further investigation, delineation and excavation of drainage and service routes across the site

- Installation of a cap in areas where there is a potential risk to future site users existing through oral exposure from metals, TPH, heavy end PAHs and asbestos

3. FURTHER WORKS – JULY-OCT 16

This section outlines the additional works recommended and described in section 2.1, carried out between July and October 2016: This comprised localised excavation at 10 locations, additional exploratory trial pits to fill in site data gaps, underground service investigation, and a third round of groundwater sampling.

3.1 Excavation Delineation

A total of 10 localised excavations were undertaken as part of the agreed soil and / or groundwater remediation programme. The activities undertaken during each excavation are described in the sections below whilst further details are included within Table 1, below.

3.1.1 General Methodology

Excavations were undertaken with an initial 5m x 5m areal extent. However, where visual and olfactory evidence of contamination was still present upon completion of the 25m^2 dig, or where validation sampling failed clean up criteria, the excavation was extended further until no visual and olfactory evidence of contamination was present and validation sampling subsequently passed.

Prior to starting any excavation, a cable avoidance tool (CAT) and signal generator were used to assess the potential presence of buried utilities. Site services plans were also reviewed prior to excavating the ground.

Excavation works were carried out using a 360° tracked excavator. Excavated material was examined for visual and olfactory evidence of contamination. If contamination was evident, the soil was stockpiled in a controlled manner and placed onto Visqueen membranes. Soil stockpiles were covered at the end of each working day. In the case no evidence of contamination was noticed within soil overburden, it was segregated, sampled and tested for the relevant contaminants, in order to assess its suitability to be re-used as backfill.

3.1.2 Asbestos Containing Excavations

Special precautions were adopted in those areas where asbestos had been previously detected. These were as follows:

- Temporary crowd barriers were installed around the excavation area, in order to restrict access to the work area
- Prior to entering the working area, all operatives (excluding excavator operatives) were required to dress in the Type 5/6 coveralls, safety wellingtons and P3 half face (face fitted) mask. Each operative was trained and accredited for working with Licensed Non Notifiable Work. When exiting the work area, all operatives (excluding excavator operatives) were required to spray down / wash their work boots and exit the work area into the decontamination area. The excavator driver was required to enter his cabin outside the working area, close the doors and windows and switch off the air conditioning system. They then tracked the machine to the work area and completed the works required
- Soil was sprayed down before breaking ground during the excavation works. The excavated soil was stockpiled on Visqueen membranes, kept damp and completely covered with a water proof membrane at the end of the day
- The excavator tracks and buckets were jet washed regularly, to remove any potential asbestos fibres
- Site monitoring for asbestos fibres in air was conducted and same day results were available using an on-site microscope to ensure the control measures were adequate

Appendix A contains the results of the onsite monitoring.

3.2 Excavation Validation Rationale

Validation soil samples were collected from the excavation and tested for the contaminants exceeding the risk assessment criteria. Soil samples were collected from each excavation (approximately, one base sample for each 25m^2 area excavated, and one side wall sample every 5m length). Excavation validation was carried out at specific depths, in order to validate the depth where the previous failure was recorded, and to also target areas where new contamination evidence was noted during remediation works. Validation depths varied, and are reported alongside the Sample ID in the laboratory results included in Appendix B.

Soils samples for laboratory testing were collected in accordance with BS5930: "The Code of Practice for Site Investigations" and BS10175: "Investigation of Potentially Contaminated Sites". Soil samples were tested in field using a Photo Ionisation Detector, in order to have an indication of the potential VOCs content and to assist with contamination delineation. Calibration certificate for this PID and records are included in Appendix C.

Soil samples were collected using appropriate sampling containers. These were labelled and then transferred into cool boxes, which were relinquished to an approved laboratory courier and laboratory.

3.3 Dewatering Validation Rationale

For some of the excavation locations, remedial actions were necessary to address the shallow groundwater contamination. The remedial action comprised dewatering from these locations by purging the excavation by means of a vac tanker.

A validation sample was collected from the re-charged water within the excavation following the purging. Water samples were analysed for the determinants exceeding the criteria generated using the detailed quantitative risk assessment modelled for that area.

Water samples were collected using appropriate sampling containers. These were labelled and then transferred into cool boxes, which were relinquished to an approved laboratory courier and laboratory. Appendix D includes the laboratory results of samples of the pumped water; Appendix E details the Waste Transfer Notes for the tankered water.

Approximately 318.15m^3 of water was pumped in total from the locations listed in Table 1. For TP28/46 and TP30 it was agreed to purge the excavations until no evidence of contamination was noticed and collect the first sample when this condition was reached. However, given the failures recorded for the first sample collected, KDC purged weekly for two weeks and collected a second sample. Given further failures on TPHs, a third sample was collected for TP28 after the yet further weekly purging. There was no requirement to resample TP40. A record of the volumes pumped from each dewatering location are provided in Table 1.

3.4 Backfilling Methodology

Any water within an excavation was removed by vacuum tanker prior to backfilling. The backfilling operations were undertaken using suitable validated overburden or imported natural virgin quarried Type 1 material.

During the backfilling operations, the infill material was compacted in layers using a 22 tonne tracked excavator.

3.5 Excavation Details

Excavation plans are included as Figure 1.

3.5.1 TP 3

Validation criteria exceedances of 1,2,4 Trimethylbenzene, Naphthalene, Aliphatic C8-C10, Aliphatic C10-12, Aromatic C10-12, Aromatic C12-16 and Aromatic C16-21 were noted from validation sample TP3 Side 1, collected during the original trial pit TP3 contamination dig.

TP3 Side 1 was initially extended a further 11m to the north. However, visual and olfactory evidence of hydrocarbon contamination present to the north, west and east led to the dig’s further extension until no visual or olfactory evidence of contamination was present. Olfactory evidence of hydrocarbon contamination within the south east corner of the TP3 excavation resulted in the dig’s extension, south. The excavation was extended until no further evidence of contamination was present and validation sampling passed.

KDC removed a roadway orientated along the western edge of the TP3 contamination dig to gain access to underlying contaminated soils. KDC also removed a concrete service duct containing redundant water pipes to ascertain whether contamination was present below it.

Part of the remedial works included removal of redundant service pipelines where these were encountered. These were followed and removed to allow the excavation of the contaminated pipe bedding and contaminated soils around them.

Dewatering was required within the excavation in order to collect dry base validation samples. Upon removal of the contamination validation samples were collected and analysed for VOCs and TPH CWG. An overburden sample was collected from 0-1.0mbgl and analysed for the full Horsham suite of analysis.

The excavation was partially backfilled using suitable crushed material available on site under a U1 Exemption registered with the Environment Agency. The remaining excavation void was backfilled with virgin Type 1 aggregate imported material. Appendix F contained laboratory data detailing the suitability of imported material.

Further details regarding the excavation are included within Table 1 below.

Table 1: Excavation Summary

** Included within TP28 excavation

Excavation ID	Start - End Date (incl backfilling)	Area (m^2)	Depth Range (m)	Soil Off Site (tonnes)	Number of Times Excavation Purged	Volume Purged (m^3 or T)	Soil Treatment/Disposal Facility
TP 3	02/08/2016 - 06/09/2016	886.25	1.0 - 3.5	2127.74	2	29.82	Biogenie - Redhill & CSG (Hydrocleansing)
TP 16	04/08/2016 - 04/08/2016	25	0-1.0	78.82	N/A	-	Biogenie - Redhill
TP28/TP46	14/09/2016 - 28/10/2016	144	2.5-3.9	1025.92	15	112.01	Biogenie - Redhill & CSG (Hydrocleansing)
TP30	13/09/2016 - 27/10/2016	6	3.5	N/A	21	63.46	CSG (Hydrocleansing)
TP 33/TP CP4	23/08/2016 - 5/09/2016	64.56	0.8-1.2	126.00	N/A	-	PJ Brown - West Hove Golf Club
TP 37	04/08/2016 - 13/10/2016	139	1.5-3.7	546.74	4	56.32	Biogenie - Redhill & CSG (Hydrocleansing)
TP40	05/09/2016 - 8/09/2016	11	-	-	5	23.81	CSG (Hydrocleansing)
TP46	13/09/2016- 28/10/2016	**	**	**	**	-	CSG (Hydrocleansing)
Former diesel tank area	13/06/2016- 02/08/2016	55.5	0-1.5	124.94	N/A	-	Biogenie - Redhill

Excavation ID	Start - End Date (incl backfilling)	Area (m^2)	Depth Range (m)	Soil Off Site (tonnes)	Number of Times Excavation Purged	Volume Purged (m^3 or T)	Soil Treatment/Disposal Facility
Building 42	14/06/2016 - 31/08/2016	300.5	1.5-1.8	1059.7	3	32.73	Biogenie Redhill & CSG (Hydrocleansing)

3.5.2 TP 16

Trial pit TP16 exceedances of Aliphatic C5-C6 and lead were noted from 0.3-1.0mbgl in the previous KDC site investigation report (ref 01140, July 2016). The exceedance was encountered within a stratum described as grey sandy gravel of mixed lithology with occasional cobbles (mainly comprising of crushed concrete, bricks and stones).

KDC excavated an area of 5m x 5m to a depth of 1.0mbgl, and allowed for the excavation, stockpiling and testing of the overburden (0-0.3mbgl) for potential re-use.

Visual and olfactory evidence of contamination was not evident when reaching the extents of the $25m^2$ excavation. Validation samples were collected from the side and base upon removal of the contaminated materials (5 samples in total) and were tested for TPH CWG and lead, with all passing the site criteria. One sample had been allowed for the testing of the overburden.

Further details regarding the excavation are included within Table 1.

3.5.3 TP28

An exceedance of the benzene SSAC was noted within the soil sample from 1.5-2.0m bgl collected from trial Pit TP28 during previous Phase 2 KDC site investigation (Ref: KDC 01140, July 2016). The exceedance was encountered within a stratum described as a red and brown slightly clayey sandy gravel with bricks, cement and gypsum.

An initial $25m^2$ area was excavated to an average depth of 3.5m bgl. The excavation was progressed from the eastern edge of the existing road towards the Building 21 footprint, in order to avoid disturbing potential underground drainage present below the centre of the road.

Visual evidence of contamination was still noted when reaching the extents of the $25m^2$ excavation. Evidence of contamination included:

i) Multiple and uneven layers of black fine material (possible ash) mixed within the made ground from 0.5mbgl to approximately 1.6m bgl

ii) A clay pipe (approx. 6’’ diameter) orientated NW/SE at a depth ranging between 1.5-1.6m bgl and containing residues of a black sludge with a hydrocarbon odour

Excavation validation samples were therefore analysed for TPH-CWG and BTEX.

A decommissioned service duct of a rectangular cross section and constructed from reinforced concrete, orientated parallel to “Side 2” of the excavation was discovered. In order to assess the conditions of the soil below the base of the concrete duct, a number of soil samples were collected just below the duct base. To this aim, the base of duct was broken locally to allow for the soil sample collection.

Dewatering was required within the excavation. A number of water samples with sample identification “TP28-46” were collected to assess the effects of the purging activity on the residual concentration of contaminants within the water. Water validation samples were analysed for SSAC, namely PAHs, TPH-CWG and BTEX. Samples were identified with Prefix “TP28-46”.

Excavation operations were undertaken using special precautions described within section 3.1.2.

At the time of writing the backfilling of the excavation using suitably validated overburden material and type 1 imported virgin quarried infill was ongoing, details of which are within Appendix F.

Further details regarding this excavation are included within Table 1.

3.5.4 TP30

The soils within this location did not exceed the criteria for an inhalation risk. However, remedial actions were necessary to address the shallow groundwater contamination. This involved undertaking several cycles of water purging.

Given the proximity to the fence line and railway line and the obstructions present in the proximity of this location (for example, a concrete bund), the excavation was restricted to a 6m by 1m area. Further details regarding this excavation are included within Table 1.

Water validation samples were analysed for SSAC, PAHs and TPH-CWG. Overburden soil samples from 0-1.0mbgl were also collected and analysed for an asbestos Screen and quantification.

The excavation within this location was undertaken using all the precautionary measures described for asbestos containing excavations. The material arising from the excavation operations was stockpiled in a controlled manner and then used in the reversed order to backfill the excavation.

3.5.5 TP33/CP4

Black very sandy clay from 1m to 1.35m bgl with an organic odour and an exceedance of Chloromethane was recorded during the previous site Phase 2 KDC investigations (Ref: KDC 01140, July 2016) at the TP33 location.

Samples of soft black clay, including fine ash from 1.35m to 1.6m bgl, recorded an exceedance of Chloromethane at TPCP4.

Given the proximity of both the trial pit locations, the two excavations became joined as one excavation labelled "TP33/CP4". Upon removal of the contamination, validation samples were analysed for VOCs to determine if they passed the relevant SSAC (chloromethane).

Overburden soil samples from 0-1.0m bgl were collected from the TP33 and TP CP4 locations and analysed for the full Horsham site analysis suite.

The excavation was then backfilled using validated overburden soil recovered from above the contaminated material stratum.

Further details regarding the excavation are included within Table 1.

3.5.6 TP37

Exceedances of 1,2,4 Trimethylbenzene and Aliphatic C8-C10 were noted within the brown slightly clayey, sandy gravel and cobbles with a hydrocarbon odour from 1.5m-2.5m bgl during previous Phase 2 KDC site investigations at the TP37 location.

An initial 5mx5m area was excavated to a depth of 3.7m bgl. Given the proximity to the fenced railway line, the excavation was progressed from the eastern edge of the existing concrete service duct towards the site's internal perimeter road.

Visual evidence of contamination was noticed when reaching the extent of the 25m^2 excavation. Evidence of contamination included a strong hydrocarbon odour was noted within the soil below a concrete duct running from the fence line towards Building 3. Novartis was informed of the findings and instructed KDC to proceed with the uncovering and removal of the concrete service duct. The top of the duct was demolished with all pipes and cables present disconnected and removed. The concrete duct was then demolished to allow the excavation to progress.

Validation samples were analysed for the relevant SSAC, TPH CWG. It should be noted that soils exceeded the criteria at TP37 Side 2A. These could not be excavated and removed due to the proximity to the site boundary/railway rendering it unsafe to do so.

The excavation was backfilled using both the validated overburden and the imported type 1 virgin quarried material.

Further details regarding the excavation are included within Table 1.

3.5.7 TP40

The soils within this location did not exceed the criteria for an inhalation risk. However, remedial action by dewatering was necessary to address the risk posed by shallow groundwater contamination. The water within the excavation was purged several times and sampled and analysed for PAHs, BTEX and TPH CWG until the SSAC were passed.

The excavation was backfilled using the soil arising from the excavation operations.

Further details regarding the excavation are included within Table 1.

3.5.8 TP46

The soil from this location did not exceed the criteria for an inhalation risk. However, remedial action by dewatering was necessary to address the risk posed by shallow groundwater contamination.

This excavation was merged into the wider TP28 excavation. Water within the excavation was purged several times and the re-charged water sampled against validation criteria. Samples were analysed for PAHs, BTEX and TPH CWG and named TP28-46. An overburden sample (0-2.2m) was also collected and analysed for the full Horsham site analysis suite to prove its suitability for backfilling.

Given the proximity to TP28, where asbestos was known to be present, the excavation operations within this location were undertaken using all the precautionary measures for asbestos containing excavations described in section 3.1.2.

At the time of writing backfilling was being undertaken as described in Section 3.5.3 for TP28.

Further details regarding the excavation are included within Table 1.

3.5.9 Former Diesel Tank Area

Former Diesel Tank Area Side 2 validation sample exceeded the Aliphatic C10-12 and Aromatic C12-16 criteria following the original "gross excavation" driven contamination dig.

Side 2 was initially extended laterally by 3m to the west, continuing at a depth of 1.5m. However, visual and olfactory evidence of hydrocarbon contamination was still noted. The dig was then extended west laterally by 2m and to the north by 3m to remove further visual and olfactory evidence of hydrocarbon contamination.

Validation samples, analysed for TPH CWG, from the newly exposed excavation sides and base were collected upon removal of the contaminated materials (4 samples in total). All validation samples passed the site criteria.

The excavation was backfilled using the crushed material available on site under an Environment Agency U1 Exemption.

Further details regarding the excavation are included within Table 1.

3.5.10 Building 42

Side 1, 2 and 3 validation samples from the original excavation exceeded a number of Aliphatic/Aromatic TPH criteria.

The three sides were initially extended 3m to the west, north and south. However olfactory evidence of hydrocarbon contamination was still present along Side 1 and Side 2. As a result, the excavation was laterally extended a further 10m to the east, 34.5m to the north and 6m to the south until no visual or olfactory contamination was evident.

As part of the remedial works, redundant pipelines encountered were also removed to allow the excavation of the contaminated soils and pipe bedding around them.

Validation samples were analysed for TPH CWG. .

The excavation was backfilled using the crushed aggregate material available on site under an Environment Agency U1 Exemption.

Further details regarding the excavation are included within Table 1.

3.6 Underground Services Investigation

The objective of the underground service investigation trial pitting exercise was to identify gross contamination along the main redundant underground service lines, confirmed by analytical testing compared against the SSACs. The underground service lines targeted were the redundant surface water drains, foul drains and service culverts / trenches.

A total of 62no. trial pits were excavated on site and the location of these trial pits is included as Figure 1. These trial pits were identified with the prefix US and the logs are included in Appendix G.

The trial pits were excavated perpendicular to the targeted redundant underground services, using a 22t tonne excavator. Pits were excavated to the base of the targeted pipe or a maximum depth of 2m or to bedrock, whatever was the shallower.

Each trial pit was logged by a site scientist and soil samples were collected from the base of the targeted pipeline bedding material (where encountered) or excavation and the side of the excavation. Water samples were also collected from the excavation, where evidence of visual and olfactory contamination was noticed.

Soils samples for laboratory testing were collected in accordance with BS5930: "The Code of Practice for Site Investigations" and BS10175: "Investigation of Potentially Contaminated Sites". Soil samples were tested in field using a Photo Ionisation Detector, in order to have an indication of the potential VOCs content.

Soil and water samples were collected using appropriate sampling containers. These were labelled and then transferred into cool boxes, relinquished to an approved laboratory courier and transported to an approved laboratory.

3.7 Further Trial Pits

A further 12 trial pits (TP 49 to TP 60) were requested by Novartis to investigate the soil conditions along the fence line running south to east, parallel to the railway line. As requested by Novartis, six out of 12 trial pits were strategically located on the embankment, to cover an area from the start to the end of the 'former filling points' located adjacent to the railway line. The remaining six trial pits were located at the foot of the embankment to represent the areas between the ones situated on the embankment. Soil samples were analysed for the full Horsham suite.

An additional 14 trial pits (TP61 to TP74) were completed to provide further data regarding soil conditions within Building 15 footprint and the area located north east of building 3. Soil samples were analysed for the full Horsham suite.

The trial pits were excavated using a 22t tonne excavator and logged by a site scientist. Soil samples were collected from the trial pits arising's. Soils samples for laboratory testing were collected in accordance with BS5930: "The Code of Practice for Site Investigations" and BS10175: "Investigation of Potentially Contaminated Sites". Soil samples were tested in field using a Photo Ionisation Detector, in order to have an indication of the potential VOCs content.

Upon completion of the trial pit, the excavations were backfilled in a controlled manner and the material placed in reverse order to that of the excavation. After placing approximately 0.5m of material, the backfilled material was compacted using the excavator's bucket before continuing. This operation was repeated until the excavation was completely backfilled.

Due to the suspected presence of live services, trial pit TP61 was hand dug and backfilled by hand.

Water samples were also collected from the excavations, where evidence of visual and olfactory contamination was noticed.

Soil and water samples were collected using appropriate sampling containers. These were labelled and then transferred into cool boxes, which were relinquished to the approved laboratory courier and transported to the approved laboratory, for analysis of the full Horsham suite.

3.8 Additional Sampling

Shallow trial pits to a depth of 1.0m bgl were excavated at locations TP18, 24, 29, 39 and 42, in order to allow for the collection of samples from 0-1.0m bgl to determine risks to human health. Each sample was analysed for the full Horsham suite of analysis and the results incorporated into the updated site risk assessment. Appendix G contains the logs.

3.9 Groundwater Sampling (R3)

An additional round of groundwater sampling was carried out on 12th July 2016. Results are included in Appendix H.

4. HUMAN HEALTH GENERIC QUANTITATIVE RISK ASSESSMENT

4.1 Background

The findings from the GQRA in the Phase 2 report (Ref: KDC 01140, July 2016) concluded that there was a significant possibility of harm from a range of metals and PAHs across the site, and more volatile contaminants, e.g. TPH aliphatics and aromatics, and BTEX at isolated locations. Additionally, a requirement to carry out more near surface sampling (0 – 1m bgl) was highlighted.

This assessment builds on the Phase 2 June 2016 site investigation, with the addition of new exploratory hole data, validation results from remedial extents and near surface soil samples.

4.2 Summary of Approach

The risk assessment procedure is detailed further in Appendix I.

Generic Assessment Criteria (GAC) have been developed using the Contaminated Land Exposure Assessment (CLEA) package (v1.071, 2015) to assess the risk to human health from soil concentrations. GAC have only been derived for those contaminants detected above the laboratory method detection limits. Where contaminants have not been detected, it has been assumed that there is no associated risk to human health for the purpose of this assessment.

KDC understands that the development proposed for the site is likely to comprise a mixture of residential and commercial developments.

In order to take into account the various proposed land uses, two land uses have been considered. These are as follows:

- Residential with plant uptake - to provide an initial assessment of future risks to site users should an area of the site be redeveloped into residential properties with gardens
- Commercial end use - to provide an initial assessment of risks to future site users

The two models were developed in basic mode in CLEA.

The following potential exposure pathways have been considered during the assessment for both land uses:

- Dermal contact with soil
- Ingestion of soil
- Dust inhalation (indoor and outdoor)
- Vapour inhalation from soil (indoor and outdoor)
- Vapour inhalation from groundwater (indoor and outdoor)
- Consumption of home-grown produce (residential only)
- Ingestion of soil attached to vegetables (residential only)

The criteria have been derived with the following assumptions:

- A number of soil samples were analysed for organic matter. A soil organic matter (SOM) value of 0.48% and a pH of 7.86 was used within the model. These represent the geometric mean values from of 109 (SOM) and 110 (pH) samples collected during the 2016 investigations, from the made ground deposits. Note the SOM value from TP33 (1-1.3m bgl) was excluded, as this was determined to be an outlier to the data set
- A predominant soil type of sand has been conservatively selected within the model to be representative of site conditions, as per the logs

The CLEA model input parameter and output sheets are presented in Appendix J.

4.3 Assessment Criteria

4.3.1 Background

The following Generic Quantitative Risk Assessment (GQRA) uses the chemical data collected from the ground investigations to assess the risk to future site users from soil contamination.

4.3.2 Development of General Assessment Criteria

A summary of the GACs developed for both a commercial land use and a residential without plant uptake land use are presented in Table 2.

Table 2: Summary of Generic Assessment Criteria

Contaminant Detected in Soils	GAC (mg/kg)		Source
	Residential	Commercial	
Arsenic	32.4	635	CLEA V1.071
Barium	1,330	22,100	CLEA V1.071
Beryllium	51	3,970	CLEA V1.071
Boron	291	192,000	CLEA V1.071
Cadmium	5.17	230	CLEA V1.071
Chromium (III)	627	8,840	CLEA V1.071
Copper	2,330	71,700	CLEA V1.071
Lead	191*	2,320*	CLEA V1.071
Mercury (Inorganic)	169	3,640	CLEA V1.071
Nickel	121	1,670	CLEA V1.071
Selenium	350	13,000	CLEA V1.071
Vanadium	283	5,140	CLEA V1.071
Zinc	3,750	665,000	CLEA V1.071
Cyanide(Total)	15.9	17,100	CLEA V1.071
TPH (C_5-C_6 aliphatic)	1.29	389**	CLEA V1.071
TPH (C_6-C_8 aliphatic)	2.25	766**	CLEA V1.071
TPH (C_8-C_{10} aliphatic)	0.459	173**	CLEA V1.071
TPH (C_{10}-C_{12} aliphatic)	214	830**	CLEA V1.071
TPH (C_{12}-C_{16} aliphatic)	2,935	6,772	CLEA V1.071
TPH (C_{16}-C_{21} aliphatic)	88,400	1,910,000	CLEA V1.071
TPH (C_{21}-C_{35} aliphatic)	88,400	1,910,000	CLEA V1.071
TPH (C_7-C_8 aromatic)	12.4	5,067	CLEA V1.071
TPH (C_8-C_{10} aromatic)	0.765	305	CLEA V1.071

Contaminant Detected in Soils	GAC (mg/kg)		Source
	Residential	Commercial	
TPH (C_{10}-C_{12} aromatic)	4.03	1,620**	CLEA V1.071
TPH (C_{12}-C_{16} aromatic)	36.6	15,353	CLEA V1.071
TPH (C_{16}-C_{21} aromatic)	132	28,600	CLEA V1.071
TPH (C_{21}-C_{35} aromatic)	656	28,600	CLEA V1.071
Benzene	0.034	31.4	CLEA V1.071
Toluene	50.3	54,968	CLEA V1.071
Ethylbenzene	21.8	14,228.6	CLEA V1.071
Xylene-O	11.4	5,820*	CLEA V1.071
Xylene-M	10.7	5,367	CLEA V1.071
Xylene-P	10.3	5,210*	CLEA V1.071
Acenaphthene	105	109,143	CLEA V1.071
Acenaphthylene	80.2	109,165	CLEA V1.071
Anthracene	1,140	520,000	CLEA V1.071
Benzo(a)Anthracene	2.12	87.1	CLEA V1.071
Benzo(a)Pyrene	0.678	13.9	CLEA V1.071
Benzo(g,h,i)Perylene	40.9	649	CLEA V1.071
Chrysene	4.17	134	CLEA V1.071
Dibenzo(ah)Anthracene	0.994	32.9	CLEA V1.071
Fluoranthene	143	22,600	CLEA V1.071
Fluorene	79.3	72,765	CLEA V1.071
Indeno(1,2,3-cd)Pyrene	2.44	59.0	CLEA V1.071
Naphthalene	0.344	164**	CLEA V1.071
Phenanthrene	46.3	21,800	CLEA V1.071
Pyrene	309	54,200	CLEA V1.071
Chloromethane	0.0034	1.58	CLEA V1.071
2-Methylnaphthalene	6.68	7,290	CLEA V1.071
Benzo(b)Fluoranthene	4.4	98.5	CLEA V1.071

Contaminant Detected in Soils	GAC (mg/kg)		Source
	Residential	Commercial	
Styrene	3.18	2,930**	CLEA V1.071
Isopropylbenzene	2.34	1,082	CLEA V1.071
Propylbenzene	7.56	3,198**	CLEA V1.071
1,2,4 Trimethylbenzene	0.075	32.4	CLEA V1.071
Bis(2-ethylexyl)phthalate	143	85,100	CLEA V1.071
1,2-Dichloroethane	0.724	350	CLEA V1.071
Benzo(k)Fluoranthene	7.01	139	CLEA V1.071
Chlorobenzene	0.0746	52.6	CLEA V1.071
1,3-Dichlorobenzene	0.0624	25.5	CLEA V1.071
1,4-Dichlorobenzene	7.57	3,610	CLEA V1.071
1,2-Dichlorobenzene	3.43	1720	CLEA V1.071
4-Methylphenol	42.4	165,000**	CLEA V1.071

Notes:
* Based on C4SL (child) and C4SL (adult) for residential and commercial end uses respectively.
** The GAC calculated by the CLEA software exceeded the soil saturation limit for this chemical. The "effective GAC" for this compound has been calculated using the approach described in the CLEA software (v1.07) handbook. Calculations are presented in Appendix J.

The additive risk from hydrocarbons has been considered using the approach outlined within the Environment Agency (2005), The UK Approach for Evaluating Human Health Risks from Petroleum Hydrocarbons in Soils. The additive risk from the TPH fractions is calculated by determining a hazard quotient (HQ) for each TPH fraction per sample as follows:

HQ_Fi = C_Fi / GAC_Fi

Where:

HQ_Fi: Hazard quotient for TPH fraction i

C_Fi: Concentration in that sample for TPH fraction i

GAC_Fi: LQM CIEH GAC for TPH fraction i

The HQs calculated for each fraction are summed to create a hazard index (HI) per sample. Where the HI exceeds unity this can indicate a potential risk to human health. The calculations for the TPH additive risk within soils are included within Appendix K.

4.4 Risk Pathways

Where the laboratory analysis data indicate that concentrations are correlated with depth then the risk assessment has been considered with respect to three depth ranges; 0 – 0.2m, 0.2 – 1m and >1m. The exposure pathways considered for each depth are:

- **0 – 0.2m**: Direct contact with contaminated soils; inhalation/ingestion of dust generated from contaminated soils; inhalation of vapours from contaminated soils; ingestion of contaminated soils; uptake by shrubs and trees; and intake arising from construction/maintenance of buildings and services at shallow levels

- **0.2 – 1m**: Direct contact with soils at this depth has been considered; however, as direct contact with soils at depths >0.5m bgl is not normally considered except for sporadic exposure, this approach is considered to be more conservative. Sporadic exposure includes activities such as intake via ingestion/inhalation/dermal contact arising from "abnormal" (or unpredicted) excavation (e.g. children digging dens), or other purposes such as swimming pools, ponds or house extensions.

  Other pathways considered from soils at this depth range are; inhalation of vapour from contaminated soils, uptake by deep rooting shrubs and trees, intake by, or arising from, the activities of burrowing animals, intake arising from construction / maintenance of buildings and services, e.g.:

  - Foundations (usually within 2m of final formation level)
  - Water supply pipes, telecommunications, gas and power (0.5 – 1m of final formation level)
  - Sewers (from 0.5 - >1m of final formation level)

- **>1m**: Inhalation of vapours from contaminated soils

4.5 Residential End Use

4.5.1 Results

Table 3 below shows the exceedances of the residential with plant uptake GAC.

It should be noted that inorganics or heavy end hydrocarbons at depths greater than 1m are not included in this table.

Additionally, the risk from dermal and oral additive TPH exceedances are only listed for soils at depths between 0 – 1m bgl.

Table 3: Exceedances of the Residential with Plant Uptake GAC

Location	Depth (m)	Contaminants of Concern
Side 1H	1.3-1.5	Additive TPH -inhalation
Side 2G	0.3-1.5	Additive TPH - oral
Side I1	0.3-1.5	Additive TPH – oral
TP16 overburden	0-0.3	Additive TPH - inhalation
TP29	0.30-0.80	Benzo(a)anthracene
TP29	0.30-0.80	Benzo(a)pyrene
TP29	0.30-0.80	Aro16-EC21
TP3	0-1	Additive TPH - inhalation
TP3 Side 3	0.9-1.4	Additive TPH – oral and inhalation
TP 3 CONC Base Material	1.8m	Additive TPH - inhalation
TP37 Side 2A	2.60*	Ali C6-C8
TP37 Side 2A	2.60*	Ali C8-C10
TP37 Side 2A	2.60*	Ali C10-C12
TP37 Side 4B	2.5-2.8	Additive TPH - inhalation
TP39	0.30-0.60	Benzo(a)pyrene
TP3B 17 Add	1.5	Additive TPH – inhalation
TP42	0.25-0.80	Benzo(a)anthracene
TP42	0.25-0.80	Benzo(a)pyrene
TP46	0-2.2	Additive TPH - oral
TP47	0.30-0.80	Benzo(a)pyrene
TP49	0.40-0.70	Lead

Location	Depth (m)	Contaminants of Concern
TP52	0-0.4;0.9-1.2	Additive TPH - inhalation
TP54	0.15-0.70	Benzo(a)pyrene
TP58	0.50-0.80	Lead
TP58	0.5-0.8	Additive TPH - oral
TP67	1.2-1.6	Additive TPH - inhalation
TPE1	0.40-0.80	Arsenic
TPE1	0.40-0.80	Copper
TPE1	0.40-0.80	Lead
TPI1	0.4-1	Additive TPH - inhalation
TP-I2	0.50	Benzo(a)anthracene
TP-I2	0.50	Benzo(a)pyrene
TP-I2	0.50	Indeno(123cd)pyrene
TP-I2	0.50	Benzo(b)fluoranthene
US16 PIPE BASE	1.60-1.80	Ali C8-C10
US07 Side	1.20-1.60	Ali C10-C12
US07 Side	1.20-1.60	Additive TPH - inhalation
US18 BASE	2	Additive TPH - inhalation
US18 BASE	2	Ali C8-C10
US18 SIDE TANK	1.1-1.6	Ali C8-C10
US18 SIDE TANK	1.1-1.6	Ali C10-C12
US18 SIDE TANK	1.1-1.6	Additive TPH - inhalation
US18 TANK BASE	2.1	Ali C6-C8
US18 TANK BASE	2.1	Ali C8-C10
US18 TANK BASE	2.1	Ali C10-C12
US29 BASE 1	1.2	AroEC12-EC16
US33 BASE	1.1-1.6	Ali C10-C12
US33 BASE	1.1-1.6	Additive TPH - inhalation
US46 SIDE 1	1.30-1.60	Ali C8-C10
US46 SIDE 1	1.30-1.60	Ali C10-C12
US46 SIDE 1	1.30-1.60	Aro EC10-EC12
US46 SIDE 1	1.30-1.60	AroEC12-EC16
US46 SIDE 1	1.30-1.60	Additive TPH - inhalation

Location	Depth (m)	Contaminants of Concern
US50-Side	0.9-1.3	Additive TPH - oral
Key: *TP37 Side2A could not excavated fully due to proximity to railway/site boundary. (See section 3.5.6) **TP59 and TP60 have been removed as part of the TP3 remediation works.		

4.5.1 Qualitative Risk Assessment

A qualitative assessment of the risk associated with those compounds detected within soil but without GAC, has been undertaken.

A qualitative assessment has been undertaken by considering the chemical properties of these contaminants, particularly their potential to volatilise from soils. The potential for a contaminant to volatilise is measured by its Henry's Law constant. The lower the Henry's Law constant of a contaminant the less volatilization will occur. In addition the lower the vapour pressure of a substance, the less likely it is to turn into a gaseous state.

Vapour pressure is dependent on temperature and as such the vapour pressures listed in Table 4 are likely to be lower in soils than at standard temperature and pressure.

Table 4: Qualitative Assessment

Contaminant	Henry's Law Constant (atm-m³/mole)	Vapour Pressure (mm Hg at 25°C)	Likely Dominant Pathway
Carbazole	8.65E-8	1.37E-6	Soil ingestion and dermal contact
Dibenzofuran	2.14E-4	2.48E-3	Soil ingestion, dermal contact and inhalation of vapour

<table>
<tr><th>Contaminant</th><th>Henry's Law Constant (atm-m^3/mole)</th><th>Vapour Pressure (mm Hg at 25°C)</th><th>Likely Dominant Pathway</th></tr>
<tr><td colspan="4">Data taken from Hazardous Substances Databank (HSDB) (http://toxnet.nlm.nih.gov)
H < 3 x 10-7 atm-m3/mole = essentially non-volatile
H - 10-7 to 10-5 atm-m3/mole = slow volatilization
H > 10-5 to 10-3 atm-m3/mole = significant volatilization
H > 10-3 atm-m3/mole = rapid volatilization
Based on Review of Exposure Assessment Guidelines, September 1996 (US Department of Commerce, National
Technical Information Service)
Vapour pressure of some common substances (at 25°C):
Benzene = 95 mm Hg
Water = 22.8 mm Hg
Naphthalene = 0.276 mm Hg
4,4 DDE = 0.0000279 mm Hg
Benz(a)anthracene = 0.0000045 mm Hg</td></tr>
</table>

Dibenzofuran

Dibenzofuran is found in coal-tar, as a component of heat-transfer oils, as a carrier for dyeing and printing textiles, as an intermediate for production of dyes, as an antioxidant in plastics and as a component of creosote wood preservative.

Dibenzofuran was detected at ten locations (TP-I2, TP-A1, TP E1, TP35 S4, TP18, TP45, TP54, TP58, TP46 (0-2.2), TP69). It is considered that using benzo(a)pyrene as an indicator is sufficiently conservative for assessment of risks to human health due to dibenzofuran.

Carbazole

Carbazole is an anthracene derivative associated with the presence of PAHs and is found in combustion products such as those from waste incineration, tobacco smoke, aluminium manufacturing, and rubber, petroleum, coal, and wood combustion (HSDB). It has an estimated biodegradation half-life of 4.3 to 6.2 hours in soil. The Henry's Law constant of $8.65x10^{-8}$ atm-cu m/mole (25°C) indicates that carbazole will be essentially non-volatile from moist soil and water so the main routes of exposure are considered to be dermal contact and soil ingestion.

Carbazole was detected at 15 locations TPI2, TPA1, TPE1, TP33, TP35 S4, TP29, TP39, TP49, TP54, TP55, TP56, TP57, TP58, TP46 (0-2.2) and TP69. It is considered that using benzo(a)pyrene as an indicator for carbazole will be sufficiently conservative.

4.6 Asbestos

Asbestos fibres have been detected in a number of locations, as detailed in Table 5. Whilst there are no published screening criteria for asbestos in soils, consideration should be given to potential exposure in the near surface soils (<1m bgl).

Asbestos quantification testing has been undertaken on all samples where asbestos was identified in the initial screen. All samples collected in the 0-1mbgl range returned concentrations of <0.001%. This concentration would generally be considered to mean that 'trace' quantities of asbestos fibres were present (CLAIRE 2016).

Table 5: Asbestos Detection

Asbestos			
Trial Pit and Depth (m bgl)	**Characteristics**	**Type**	**Quantification Gravimetric & PCOM Total (%)**
TP29 0.30-0.80	Fibre Bundles	Amosite	<0.001
TP29 1.70-2.0	Fibre Bundles in cement debris	Chrysotile	0.022
TP29 2.5-3.0	Free fibres	Chrysotile	<0.001
TP30 1.0-1.70	Free fibres	Chrysotile	<0.001
TP30 2.0-3.0	Free fibres	Chrysotile	<0.001
TPE1 0.40-0.80	Fibre Bundles	Chrysotile	<0.001
TP39 0.30-0.60	Fibre Bundles	Chrysotile	<0.001
TP39 0.90-1.00	Fibre Bundles	Chrysotile	<0.001
TP18 0.00-0.50	Fibre Bundles	Chrysotile	<0.001
TP58 0.05-0.50	Fibre Bundles	Chrysotile	<0.001

Asbestos			
Trial Pit and Depth (m bgl)	**Characteristics**	**Type**	**Quantification Gravimetric & PCOM Total (%)**
TP52 0.00-0.40	Fibre Bundles	Chrysotile	<0.001
TP52 0.90-1.20	Fibre Bundles	Amosite	<0.001
TP28 - ADD 0.2-1.0	Fibre Bundles	Chrysotile	<0.001
TP46 (0-2.2)	Fibre Bundles	Chrysotile	<0.001
TP28-CONCRETE	Fibre Bundles	Chrysotile	<0.001

Soil samples in trial pits TPE1, TP29, TP39, TP18, TP58, TP52, TP28, TP30, and TP46 all reported trace asbestos within in near surface soils (0 – 1m). Although these concentrations are considered to present a low risk, it may not be considered negligible. It is recommended that the material at these locations is capped.

Trace asbestos fibres were also noted in sample TP28-CONCRETE. This material has been removed from site along with asbestos contaminated soils from the TP28 excavation.

Suitable capping of this material is likely to include covering with hardstanding or 'clean' material (300mm), and possibly including geomembrane.

4.7 Commercial

No significant possibility of significant harm has been identified for future site users, assuming a commercial end use.

4.8 Summary

4.8.1 Residential End Use

The GQRA indicated risks to future residential site users via the oral pathway at a number of locations:

- Side 2G – additive TPH
- Side I1 – additive TPH
- TP29 – PAHs and TPH
- TP3 - additive TPH
- TP39 – PAHs
- TP42 – PAHs
- TP46 – additive TPH
- TP49 – metals
- TP52 – additive TPH
- TP54 – PAHs
- TP58 –metals and additive TPH
- TPE1 – metals
- TP12 – PAHs
- US 50 - additive TPH

Risks to future site users from an inhalation pathway were found at:

- US16 - TPHs
- US07 - additive TPH
- US18 - TPHs
- US29 - TPHs
- US33 - TPHs
- US46 – TPHs

- Side IH – additive TPH
- TP16 Overburden – additive TPH
- TP37 – TPHs
- TP67 – additive TPH
- TPI1 – additive TPH

Initial recommendations were made to excavate the soils at US18 and Us46 is recommended; an underground tank was found during initial works at the former, and could be acting as a source. A number of aliphatic and aromatic factions were found to exceeded the GAC at US46.

Further statistical analysis of the data set was recommended to determine if the true mean of the population is less than the critical concentrations.

Additionally a detailed quantitative risk assessment was recommended with refined exposure scenarios. This would determine whether soils at depth present a risk to future site users.

This is detailed further in Section 6.

4.8.2 Commercial

No significant possibility of significant harm has been identified assuming a commercial end use.

4.8.3 Asbestos

Soil samples in trial pits TPE1, TP29, TP39, TP18, TP58, TP52, TP28, TP30, and TP46 all reported trace asbestos within in near surface soils (0 – 1m). Although these concentrations are considered to present a low risk, it may not be considered negligible. It is recommended that the material at these locations is capped.

Trace asbestos fibres were also noted in sample TP28-CONCRETE. This material was removed from site along with asbestos contaminated soils from the TP28 excavation.

Suitable capping of this material is likely to include covering with hardstanding or ‘clean’ material, and possibly including geomembrane.

5. RISKS TO WATER ENVIRONMENT

5.1 Background

The primary recommendations of the Phase 2 Environmental Investigation Report (Ref: KDC 01140, July 2016) were to carry out an additional round of groundwater sampling (round 3) and undertake a DQRA assessment for risk to the water environment in terms of underlying groundwater and off site controlled waters.

This chapter details firstly the updated generic quantitative risk assessment to take account of additional groundwater sampling and leachate analysis from new trial pits, and also the DQRA of potential soil and groundwater sources impacting either underlying groundwater and offsite sources.

5.2 GQRA

5.2.1 Background

Reference should be made to the approach detailed in the Phase 2 Environmental Investigation Report (Ref: KDC 01140, July 2016). In order to protect the future resource potential of the aquifer, measured leachate and groundwater concentrations have been compared against Resource Protection Values (RPVs) (Appendix O). The RPVs are drawn from the following information sources:

- DWS referenced within European Directive 98/83/EC the Drinking Water Directive
- World Health Organisation (WHO) Guidelines for Drinking Water Quality 1993
- England and Wales, The Water Supply (Water Quality) Regulations 2000
- UK Technical Advisory Group on the Water Framework Directive Application of Groundwater Standards to regulation 2011

Risks to surface water receptors have been considered by screening the leachate and groundwater results against the following assessment limits:

- Environmental Quality Standards (EQS) for rivers and freshwater lochs as outlined within Water Framework Directive implementation in England and Wales: new and updated standards to protect the water environment 2014 (Appendix O).

5.2.2 Risks to Surface Water

Soil source

Risks to surface water receptors have initially been assessed based on a direct comparison of soil leachate results against freshwater EQS criteria. The table below and included in Appendix L summarises those contaminants noted to be present within the leachate at concentrations in excess of their respective EQS values.

Table 6: Leachate EQS exceedance summary

Location	Depth (m)	Contaminants
TP63	1.2-3.0	Chromium
TP7	1.40-1.90	
TP21	1.50-2.10	
TP14	0.50-1.00	Nickel
TP14	0.50-1.00	Zinc
TP63 SIDE	1.2-3.0	Fluoranthene
TP21	1.50-2.10	
TP62 BASE	2	
TP21	1.50-2.10	Benzo(a)pyrene
TP21	1.50-2.10	Hexavalent Chromium

Groundwater source

Groundwater samples from boreholes and trial pits were collected and screened against the fresh water EQS screening criteria. It is noted that water collected from trial pits is not necessarily representative of aquifer conditions. Table 7 and Appendix M summaries where groundwater concentrations exceeded the EQS assessment criteria.

Table 7: Level 2 Groundwater EQS Exceedances

Level 2 Groundwater EQS Remedial Target Exceedances						
Contaminant	**Unit**	**EQS Screening Value**	**Exceedances in Feb 2016 BH1, BH2 (Location and concentration)**	**R1 Exceedances Location (concentration)**	**R2 Exceedances Location (concentration)**	**R3 Exceedances Location (concentration)**
Dissolved Cadmium	ug/l	0.08	-	-	BH5(0.9) BH7 (0.6)	-
Total Dissolved Chromium	ug/l	4.7	BH1 (8.5)	BH8 (15.6)	BH4 (58.5)	-
Dissolved Copper	ug/l	1	BH1	BH4 (9)	BH4(47)	BH1 (7) BH4 (23) BH5 (9) BH8 (8)
Dissolved Nickel	ug/l	4	BH1(7) BH2(5)	BH2(18) BH4(8) BH5(39) BH7(31) BH8(8)	BH1(7) BH2(16) BH4(21) BH5(65) BH7(26)	BH1 (5) BH2 (7) BH4 (17) BH5 (35) BH7 (14) BH6 (7)
Dissolved Vanadium	ug/l	20	-	-	-	BH4 (38.8) BH5 (21.6)
Dissolved Zinc	ug/l	8	-	BH5(15), BH7 (39)	BH-5 (38) BH-7 (32)	BH6 (16) BH7 (13)

Level 2 Groundwater EQS Remedial Target Exceedances						
Contaminant	**Unit**	**EQS Screening Value**	**Exceedances in Feb 2016 BH1, BH2 (Location and concentration)**	**R1 Exceedances Location (concentration)**	**R2 Exceedances Location (concentration)**	**R3 Exceedances Location (concentration)**
Anthracene [#]	ug/l	0.1	BH1 (0.12)	-	-	-
Fluoranthene [#]	ug/l	0.0063	BH1 (0.06)	BH1 (0.02) BH5 (0.02) BH7 (0.03)	BH-1 (0.05) BH-4 (0.17) BH-5 (0.03)	BH1 (0.03) BH4 (0.04)
Benzo(a)pyrene	ug/l	0.00017	-	BH7 (0.02)	BH-4 (0.08)	
Phenol	ug/l	7.7	BH1 (9)	BH1 (12)	-	BH5 (61)
Aliphatics >C5-C6	-	-	-	-	-	BH5 (35)
Aliphatics >C6-C8	-	-	-	-	-	BH5 (56)
Aliphatics >C8-C10	-	-	-	-	-	BH5 (64)
Aromatic >EC8-EC10	-	-	-	-	-	BH5 (6)
Aromatic >EC10-EC12	-	-	BH1 (47)	BH1 (69)	-	
Aromatic >EC12-EC16	-	-	BH1 (120)	BH1 (210)	-	
Aromatic >EC16-EC21	-	-	-	BH1 (180)	-	
Aromatic >EC21-EC35	-	-	-	BH1 (70)	-	
Hexavalent Chromium	-	-	-	BH8 (10)	BH-4 (53)	

5.2.3 Risks to Groundwater Water

Soil source

Risks to groundwater has initially been assessed based on a direct comparison of soil leachate results against RPV criteria. Contaminants that exceed of their respective RPV values are included in Table 8. Appendix L summarises those contaminants noted to be present within the leachate at concentrations in excess of their respective RPV values.

Table 8: Leachate RPV Exceedance Summary

Location	Depth (m)	Contaminants
TP21	1.50-2.10	B(a)P

Groundwater source

Groundwater samples from boreholes and trial pits were collected and screened against the RPV screening criteria. It is noted that water collected from trial pits is not necessarily representative of aquifer conditions. Table 9 and Appendix M summaries where groundwater concentrations exceeded the RPV assessment criteria.

Table 9: Level 2 Groundwater RPV Exceedances

Level 2 Groundwater RPV Remedial Target Exceedances						
Contaminant	**Unit**	**RPV Screening Value**	**Exceedances in Feb 2016 BH1, BH2 (Location and concentration)**	**Exceedances R1 (Location and concentration)**	**Exceedances R2 (Location and concentration)**	**Exceedances R3 (Location and concentration)**
Arsenic	ug/l	10	**-**	**-**		BH4 (12)
Dissolved Cadmium	ug/l	0.1	-	-	BH5 (0.9) BH7 (0.6)	
Total Dissolved Chromium	ug/l	50	-	-	BH4 (58.5)	-
Dissolved Nickel	ug/l	20	-	BH5 (39), BH7 (31)	BH4 (21), BH5 (65), BH7 (26)	BH5 (35)
Dissolved Selenium	ug/l	10	-	BH4 (40)	BH4 (32), BH-5 (12)	BH5 (11)
Benzo(a)pyrene	ug/l	0.01	-	BH7(0.02)	BH4 (0.08)	-
Aliphatic C5-C6	ug/l	5	-	-	-	BH5 (35)
Aliphatic C6-C8	ug/l	5	-	-	-	BH5 (56)
Aliphatic C8-C10	ug/l	5	-	-	-	BH5 (64)
Aromatic >EC8-EC10	ug/l	5	-	-	-	BH5 (6)
Aromatic >EC10-EC12	ug/l	**5**	BH1 (47)	BH1 (69)	-	-
Aromatic >EC12-EC16	ug/l	**10**	BH1 (120)	BH1 (210)	-	-

Level 2 Groundwater RPV Remedial Target Exceedances						
Contaminant	**Unit**	**RPV Screening Value**	**Exceedances in Feb 2016 BH1, BH2 (Location and concentration)**	**Exceedances R1 (Location and concentration)**	**Exceedances R2 (Location and concentration)**	**Exceedances R3 (Location and concentration)**
Aromatic >EC16-EC21	ug/l	**10**	-	BH1 (180)	-	-
Aromatic >EC21-EC35	ug/l	**10**	-	BH1 (70)	-	-

5.3 DQRA Approach

At the site, both the underlying groundwater and controlled waters have the potential to be impacted from leaching of contaminants from identified soil sources and/or the lateral migration of contaminants in the groundwater towards offsite receptors.

The Environment Agency Remedial Targets Methodology (RTM) spreadsheet was used to calculate Level 2 and Level 3 soil assessment criteria for those contaminants detected in groundwater on more than one occasion at any given exploratory hole to be protective of underlying groundwater as a resource and for offsite receptors, respectively. Additionally Level 3 groundwater assessment criteria for those contaminants detected in groundwater more than once were generated to be protective of offsite receptors.

The made ground onsite is considered to be the primary shallow aquifer, dominated by contaminant migration from source areas towards the nearest surface water receptor. Separate modelling of groundwater flow within the bedrock receptor was not considered justified, as the desk study highlighted the bedrock to be a secondary aquifer/ unproductive strata. The relevant pollutant linkages, as they relate to the RTM spreadsheet, are described in Table 10 below.

It is considered that the groundwater lying within the Made Ground is flowing in a predominantly south-westerly direction ultimately towards Horsham Park Pond.

The site specific input parameter values for the RTM model are presented in Tables 11, 12, 13 and 14, and the RTM model outputs are presented in Appendix N. A summary of chemical properties used in the RTM modelling is presented in Appendix O.

Table 10: RTM Linkages

Source	Adopted Receptor for RTM	Migration Pathways	Target Concentration	Relevant RTM Tiers
Made ground	Underlying groundwater	Infiltration, leaching and advection in shallow groundwater.	RPV	Soil 1, and 2
Made ground	Horsham Park Pond	Infiltration, leaching and advection in shallow groundwater with anaerobic biodegradation in the dissolved phase.	EQS	Soil 1, 2 and 3
Shallow groundwater in Area AC1	Horsham Park Pond	Advection in shallow groundwater with anaerobic biodegradation in dissolved phase.	EQS	Groundwater 3

Table 11: Level 1 Soil RTM Model Inputs

Parameter	Units	Value	Justification
Water filled porosity	fration	0.24	Representative of sand (EA SR3, 2009, table 4.4).
Air filled porosity	fration	0.3	Representative of sand (EA SR3, 2009, table 4.4).
Bulk density of soil zone material	g/cm^3	1.18	Representative of sand (EA SR3, 2009, table 4.4).
Fraction of organic carbon	fration	0.00278	Derived from an SOM of 0.48%. SOM is geomean of all soils result minus high outlier SOM values.

Table 12: Level 2 Soil RTM Model Inputs

Parameter	Units	Value	Justification
Infiltration	m/d	0.00056	MET office - Charlwood station = 818.8mm/ year average. Assume 25% infiltration.
Area of soil source	m2	41600	260m length x 160m width
Length of contaminant source in direction of groundwater flow	m	Contaminant specific	Contaminant specific areas identified across the site
Saturated aquifer thickness	m	0.59	Geomean of the depth to bedrock minus the geomean of the depth to groundwater.
Hydraulic conductivity of aquifer	m/d	6.359	Representative of sand (EA SR3, 2009, table 4.4).
Hydraulic gradient of water table	-	0.01	Average gradient calculated based on measured groundwater levels between BH4 and BH6
Width of contaminant source perpendicular to groundwater flow.	m	Contaminant specific	Contaminant specific areas identified across the site
Background concentration of contaminant in groundwater beneath the site	mg/l	Contaminant specific	Half of laboratory detection limit. Where the detection limit is more than the target concentration (CT) then the background concentration is set at zero.
Mixing zone thickness	m	0.59	Geomean of the depth to bedrock minus the geomean of the depth to groundwater.

Table 13: Level 3 Soil RTM Model Inputs

Parameter	Units	Value	Justification
Bulk density of aquifer materials	g/cm^3	1.18	Environment Agency 2009 SC0500021/SR3
Effective porosity of aquifer materials	Fraction	0.24	Environment Agency 2009 SC0500021/SR3
Fraction of organic carbon	fr	0.00278	Derived from an SOM of 0.48%. SOM is geomean of all soils result minus high outlier SOM values.
Distance to compliance point	m	150	BH2 to north site boundary
Time since pollutant entered groundwater	Years	3.65E+06	Representing a glacial period
Longitudinal dispersivity	m	15	Dispersivities 10%, 1%, 0.1% of pathway length
Transfer to dispersivity	m	1.5	Dispersivities 10%, 1%, 0.1% of pathway length
Vertical dispersivity	m	0.15	Dispersivities 10%, 1%, 0.1% of pathway length

Table 14: Level 3 Groundwater RTM Model Inputs

Parameter	Units	Value	Justification
Width of plume in aquifer at source (perpendicular to flow)	m	5 - 157	*Contaminant specific*
Plume thickness at source	m	0.59	Geomean of depth to bedrock minus the geomean of the depth to groundwater
Saturated aquifer thickness	m	0.59	Geomean of depth to bedrock minus the geomean of the depth to groundwater
Bulk density of aquifer materials	g/cm^3	1.18	Environment Agency 2009 SC0500021/SR3
Effective porosity of aquifer	-	2.40E-01	Environment Agency 2009 SC0500021/SR3
Hydraulic gradient	-	1.20E-02	*Geomean of difference in groundwater levels of (BH8-BH7, BH6-BH7, BH5-BH7) in all three rounds*

Parameter	Units	Value	Justification
Hydraulic conductivity of aquifer	m/d	6.36E+00	Sand Value from Environment Agency 2009 SC0500021/SR3
Distance to compliance point	m	1.30E+01	*TP28 to south site boundary*
Distance (lateral) to compliance point perpendicular to flow direction	m	0	Assumes pathway is in centre-line of the plume
Distance (depth) to compliance point perpendicular to flow direction	m	0	Assumes pathway is in centre-line of the plume
Time since pollutant entered groundwater	Years	3.65E+06	Representing a glacial period
Longitudinal dispersivity	m	18.9	10% of pathway length
Transverse dispersivity	m	1.89	1% of pathway length
Vertical dispersivity	m	0.189	0.1% of pathway length

5.4 Remedial Targets Methodology Outputs

Table 15 below shows the Level 2 soil remedial targets calculated using the remedial targets methodology spreadsheet. These have been applied to concentrations of chemicals detected in the soil across the site.

Table 15: Level 2 Soil Remediation Targets

Level 2 Soil RPV		
Contaminant	mg/l	mg/kg
Ali C5-C6	6.50E-03	7.08E-02
Ali C6-C8	6.55E-03	1.58E-01
Ali C8-C10	6.55E-03	7.16E-01
Ali C12- C16	1.31E-02	2.02E+01

Level 2 Soil RPV		
Contaminant	mg/l	mg/kg
Ali C16-C21	1.31E-02	2.32E+04
Ali C21-C35	1.31E-02	2.32E+04
Aro EC12-EC16	1.31E-02	1.87E-01
Aro EC16-EC21	1.31E-02	5.88E-01
Aro EC21-EC35	1.31E-02	4.64E+00
B(a)P	1.31E-05	3.75E-02
p-xylene	3.93E-03	5.99E-03
m-xylene	3.93E-03	6.40E-03

Table 16 below shows the Level 3 soil remedial targets calculated using the remedial targets methodology spreadsheet. These have been applied to concentrations of chemicals detected in the soil across the site.

Table 16: Level 3 Soil Remediation Targets

Level 3 Soil EQS		
Contaminant	mg/l	mg/kg
Ali C5-C6	3.64E-01	3.94E+00
Ali C6-C8	3.64E-01	8.77E+00
Ali C8-C10	3.64E-01	3.98E+01
Ali C10-C12	1.92E-01	1.41E+02
Ali C12- C16	2.52E-01	3.88E+02
Ali C16-C21	No impact	No impact
Ali C21-C35	No impact	No impact
Aro EC12-EC16	2.18E-01	3.11E+00
Aro EC16-EC21	3.84E-01	1.72E+01
Aro EC21-EC35	1.97E-01	6.97E+01
B(a)P	7.60E-05	2.18E-01
Chromium III	8.78E-02	3.78E+05
Chromium	8.78E-02	1.06E-01
Copper	3.96E+01	1.09E+06

Level 3 Soil EQS		
Contaminant	mg/l	mg/kg
Fluoranthene	4.13E-04	1.24E-02
Chromium VI	6.35E-02	9.02E-01
Nickel	7.47E-02	1.08E+01
Lead	2.24E-02	6.10E-01
Phenol	5.60E-01	4.45E-02
Zinc	No impact	No impact

Table 17 below shows the Level 3 groundwater remedial targets calculated using the remedial targets methodology spreadsheet. These have been applied to concentrations of chemicals detected in the soil across the site.

Table 17: Level 3 Groundwater Remediation Targets

Level 3 Groundwater EQS	
Contaminant	mg/l
Ali C5-C6	8.11E-03
Ali C6-C8	6.48E+00
Ali C8-C10	6.48E+00
Ali C10-C12	9.91E-01
Ali C12- C16	8.58E+01
Ali C16-C21	No impact
Ali C21-C35	No impact
Aro EC5-EC7	No impact
Aro EC7-EC8	1.02E+01
Aro EC8-EC10	9.58E-01
Aro EC10-EC12	2.98E-01
Aro EC12-EC16	2.64E-01
Aro EC16-EC21	1.96E-01
Aro EC21-EC35	3.44E+00
B(a)P	2.79E-06
Benzene	2.04E+01

Level 3 Groundwater EQS	
Contaminant	mg/l
Cadmium	1.14E-01
Chromium III	No Impact
Chromium VI	4.85E-02
Chromium	No impact
Copper	No impact
Ethylbenzene	1.27E+01
Fluoranthene	1.01E-04
m-xylene	6.12E+01
Naphthalene	1.27E+00
Nickel	5.71E-02
o-xylene	6.12E+01
phenol	9.97E+00
p-xylene	6.12E+00
Toluene	6.90E+02
Vanadium	2.85E-01
Zinc	No impact

5.4.1 Sensitivity Analysis

Conservative values were chosen for the groundwater hydraulic gradient based on site investigation information. In the absence of site specific data, literature values were taken for hydraulic conductivity. There is uncertainty as to the real values of these aquifer properties and as such it was considered valuable to conduct model sensitivity analysis for these input parameters.

The remedial targets for soil and groundwater were calculated using the estimated values for hydraulic conductivity and calculated average hydraulic gradient as presented in Table 12 and Table 14 above.

In addition, the effective porosity of the aquifer is unknown and likely to be variable across the site. The selected value varied by + and – 25% around the chosen values.

Each input parameter value was varied in isolation in order to limit the number of model iterations that were required, as well as providing a clearer picture of the sensitivity of the model.

The sensitivity analysis was carried out for benzo(a)pyrene, aliphatic C5-6 and aromatic C12-16. Metals were not included in the sensitivity analysis as the screening criteria for metals are not affected by these input parameters.

The results of the sensitivity analysis are presented below.

Table 18: Sensitivity Analysis for Benzo(a)pyrene

Parameter	Change in value	Value used	Level 2 soil AC (mg/kg)	Level 3 soil AC (mg/kg)	Level 3 GW AC (mg/l)
Hydraulic conductivity (m/d)	+25%	7.948	$3.97E^{-2}$	$9.97E^{-3}$	$1.02E^{-5}$
	Literature value	6.359	$3.75E^{-2}$	$9.47E^{-3}$	$2.21E^{-5}$
	-25%	5.0872	$3.57E^{-2}$	$9.08E^{-3}$	$6.21E^{-5}$
Hydraulic gradient	+25%	0.0125	$3.79E^{-2}$	$9.55E^{-3}$	$1.88E^{-5}$
	Average	0.01	$3.75E^{-2}$	$9.47E^{-3}$	$2.21E^{-5}$
	-25%	0.008	$3.49E^{-2}$	$8.22E^{-3}$	$1.83E^{-5}$
Effective aquifer porosity (fraction)	+25%	0.3	N/A	$9.53E^{-3}$	$2.23E^{-5}$
	0	0.24	N/A	$9.47E^{-3}$	$2.21E^{-5}$
	-25%	0.192	N/A	$9.42E^{-3}$	$2.18E^{-5}$

Table 19: Sensitivity Analysis for Aromatic C_{12}-C_{16}

Parameter	Change in value	Value used	Level 2 soil AC (mg/kg)	Level 3 soil AC (mg/kg)	Level 3 GW AC (mg/l)
Hydraulic conductivity (m/d)	+25%	7.948	$1.98E^{-1}$	$3.27E^{+0}$	-
	Literature value	6.359	$1.87E^{-1}$	$3.11E^{+0}$	-
	-25%	5.0872	$1.78E^{-1}$	$2.98E^{+0}$	-
Hydraulic gradient	+25%	0.0125	$1.89E^{-1}$	$3.14E^{+0}$	-
	Average	0.01	$1.87E^{-1}$	$3.11E^{+0}$	-
	-25%	0.008	$1.72E^{-1}$	$2.90E^{+0}$	-
Effective aquifer porosity (fraction)	+25%	0.3	N/A	$3.12E^{+0}$	-
	0	0.24	N/A	$3.11E^{+0}$	-
	-25%	0.192	N/A	$2.91E^{+0}$	-

Table 20: Sensitivity Analysis for Aliphatic C_5-C_6

Parameter	Change in value	Value used	Level 2 soil AC (mg/kg)	Level 3 soil AC (mg/kg)	Level 3 GW AC (mg/l)
Hydraulic conductivity (m/d)	+25%	7.948	$7.50E^{-2}$	$3.90E^{+0}$	$1.95E^{-2}$
	Literature value	6.359	$7.09E^{-2}$	$3.94E^{+0}$	$2.43E^{-2}$
	-25%	5.0872	$6.75E^{-2}$	$3.98E^{+0}$	$3.18E^{-2}$
Hydraulic gradient	+25%	0.0125	$7.16E^{-2}$	$3.93E^{+0}$	$2.33E^{-2}$
	Average	0.01	$7.09E^{-2}$	$3.94E^{+0}$	$2.43E^{-2}$
	-25%	0.008	$6.53E^{-2}$	$4.02E^{+0}$	$4.11E^{-2}$
Effective aquifer porosity (fraction)	+25%	0.3	N/A	$5.30E^{+0}$	$2.49E^{-2}$
	0	0.24	N/A	$3.94E^{+0}$	$2.43E^{-2}$
	-25%	0.192	N/A	$3.07E^{+0}$	$2.39E^{-2}$

5.5 Risk to Groundwater Resource

5.5.1 Soil Source

The RTM Level 2 soil screening criteria (Table 15) were applied to the soils across the site and the following exceedances were noted:

- Benzo(a)pyrene – widespread
- p/m xylene – widespread
- Aromatic C12-C16 – widespread
- Aromatic C16-21 – widespread
- Aromatic C21-35 widespread
- Aliphatic C5-C6 – TP3 Side, TP16 OB, TP37 2A, TP3 S2T, T3 S3A, TP3, TP28 side 2b, TP10, BH8, TP60, TP59, Building 4 side 18 Add
- Aliphatic C6-C8 – TP37 Side 2A, TP10, Building 42 side 1B, TP28 Side 2b add, BH8, US46 Side 1, US18 Side tank, US18 Tank Base, US 18 Base
- Aliphatic C8-10 – TP37 Side 2A, TP10, Building 42 side 1B, TP28 Side 2b add, BH8, US46 Side 1, US18 Side tank, US18 Tank Base, US16 Pipe Base
- Aliphatic C12-C16 – US33 Base, US29 Base 1, US46 Side 1

Appendix P details the soil screening against the level 2 soil ACs.

5.5.2 Discussion

The results of the L2 soil assessment indicates that there is a potential for pollution to enter groundwater due to leaching of these chemicals from soil.

Metals exceeded the RPV on several rounds at BH4, BH5 and BH7, with isolated hydrocarbon exceedances across the site. The removal of hydrocarbon contaminated soils, combined with the extensive groundwater pumping regime is likely to have had a positive effect on the groundwater quality.

Additionally, given that there are no abstractions within 1km of the site, it is unlikely that groundwater will be abstracted from the made ground aquifer in the near future.

These contaminants are not being repeatedly detected above the RPV in groundwater samples. This is backed up by the lack of RPV leachate exceedances in table 19. It is likely that the model is being conservative in the partitioning and over predicting leachate concentrations.

5.6 Risk to Surface Water

5.6.1 Soil Source

The RTM Level 3 soil screening criteria (Table 16) were applied to the soils across the site and the following exceedance were noted:

- Chromium – widespread
- Lead – widespread
- Nickel –widespread
- Fluoranthene – widespread
- Benzo(a)pyrene – widespread
- Aliphatic C12-C16 – US46 Side 1 – 1.3-1.6m bgl
- Aromatic C12-C16 – widespread
- Aromatic C16-21 – widespread
- Aromatic C21-35 – widespread
- Hexavalent Chromium – TP13 1.5mbgl; TP15 – 2.1-2.3mbgl.

Appendix P details the soil screening against the level 3 soil ACs.

5.6.2 Groundwater Source

The RTM Level 3 groundwater screening criteria (Table 17) were applied to the groundwater samples across the site and the following exceedance were noted:

- Nickel - BH 5 (R2)
- Fluoranthene BH4 (R2)
- Benzo(a)pyrene - BH4 (R2), BH7(R1)
- Aliphatic C5-C6 - BH5 (R1)
- Hexavalent chromium – BH4 (R2)

Appendix P details the soil screening against the level 3 groundwater ACs.

5.6.3 Discussion

The results of the L3 soil and groundwater assessments indicate that there is a potential for pollution to controlled waters due to leaching of these chemicals from soil, and lateral migration

It is likely that the RTM model is being conservative in the partitioning and over predicting leachate concentrations. This is backed up by the limited number of EQS leachate exceedances, as per Table 6. In fact, out of 12 leachate samples which were tested for metals, PAHs, VOCs and TPHs only ten contaminants failed in total – three for chromium and three for fluoranthene and one exceedance each for nickel, zinc, B(a)P and hexavalent chromium. On review of the groundwater concentrations beneath the site (table 7) there are elevated concentrations of copper, nickel, fluoranthene and zinc across the site on multiple rounds. Given these are not repeated in multiple samples in the leachate results, expect for fluoranthene and on one occasion for zinc, it is likely that a soil source is not acting as an ongoing source of contamination except in isolated locations for fluoranthene and zinc. This is consistent with the history of development of the site – made ground was imported in the 1930s and that any metals are likely to have leached by now.

In terms of risk from groundwater sources, there are elevated concentrations of metals and PAHs on site in the groundwater as a result of historical leaching; there are no elevated concentrations in BH6, the up-gradient borehole, therefore the source can only have come from site. However, on review of the L3 groundwater AC exceedances there are no repeated failures across the site for PAHs and metals; therefore it can be concluded that there is no significant groundwater source on site that could impact an offsite receptor.

It is therefore concluded that there is no requirement for any additional remedial measures.

5.7 Pumping Activities

Localised repeated dewatering has been undertaken in the vicinity of TP40, TP28, TP46 and TP30. Purged volumes are indicated in the table below.

Table 21: Excavation Purging

.	Building 8	Building 11	Building 42	TP3	TP30	TP37	TP28/46	TP40	US46	US18	TP52
No. of purges				2	21	4	15	5	n/a	n/a	n/a
			13510	13510							
	27320	16180	11860								
	0	19200	7360	7360							
		10780		3160							
		640		5773		5773	5773				
				20		20		20			
		23340				13360		13360			
		17120				26740					
						10430		10430			
					6800		6800				
							25960				
					110		110				
					13400		13400				
							16820				
					12600		12600				
					7770		7770				
					8960		8960				
					8300		8300				
					370		370				
					9550		9550				
					5015		5015		10030		
									13900		

.	Building 8	Building 11	Building 42	TP3	TP30	TP37	TP28/46	TP40	US46	US18	TP52
									220		
									13140		
									7240		
									15440		
										10250	10250
										5820	
										60	
kg	27320	87260	32730	29823.33	72875	56323.33	121428.3333	23810	59970	16130	10250
m3	**27.32**	**87.26**	**32.73**	**29.82333**	**72.875**	**56.32333**	**121.4283333**	**23.81**	**59.97**	**16.13**	**10.25**
average purge vol				14.91167	3.4702381	14.08083	8.095222222	4.762	n/a	n/a	n/a
total pumped water		537.92	m3								

A review of final pumping concentrations against the L3 GW (EQS) and RPV SSACs concentrations was carried out.

Table 22: Final Excavation Pumping Quality

Location	Date	Contaminant of Concern	SSAC	SSAC ug/l	Concentration ug/l
TP28/46	18/10/2016	Fluoranthene	L3 GW	0.101	0.2
TP28/46	18/10/2016	Benzo(a)pyrene	L3 GW	0.00279	0.06
TP28/46	18/10/2016	Benzo(a)pyrene	RPV	0.0100	0.06
TP30	12/10/2016	Fluoranthene	L3 GW	0.101	0.31
TP30	12/10/2016	Benzo(a)pyrene	L3 GW	0.00279	0.016

Previous rounds of groundwater monitoring indicated that B(a)P and fluoranthene groundwater concentration across the site were low and only elevated in this part of the site, suggesting a localised soil source i.e. TP28/46 and TP30. Significant excavation of contaminated soil has now been carried out in this vicinity and significant volumes of groundwater purged. During the purging, benzo(a)pyrene and fluoranthene dissolved phase concentrations have fluctuated with some rounds returning concentrations below MLD suggesting the dominant source is in the soil, as opposed to the groundwater. Therefore, by removing the soil source, local groundwater betterment will be inevitable. This has already been demonstrated at TP30, where there has been a demonstrable improvement in PAH chemistry, as a result of the soil source removal.

5.8 Summary

It is concluded that there is a low risk of significant potential for significant harm to both either underlying groundwater and controlled waters from soils and groundwater on site.

6. FURTHER WORKS AND DETAILED QUANTITATIVE RISK ASSESSMENT

6.1 General

This section details the further site works and detailed quantitative human health risk assessment (HH DQRA) carried out, following the GQRA of the remediation excavations.

6.2 Further Excavations – US18, US46

The findings of the GQRA, as per section 4, state that future residential site users at certain locations could be at risk from inhalation of light-end aliphatics and aromatics or by the risk from additive TPH. Further excavation would be required to mitigate such a risk. Initially, these excavations targeted US18 and US46, given that multiple fractions of TPH CWG generic acceptance criteria (GAC) failures were recorded here, whilst the DQRA and statistical analysis were being progressed for the other excavation areas. Excavations were extended to remove potential sources and validated for TPH CWG. Figure 1 shows the extent of these excavations.

6.2.1 US18

KDC exposed a redundant underground steel petrol storage tank at the US18 location during the underground service investigation trial pitting exercise. Criteria (GAC) exceedances of Aliphatic C8-C10 and Aliphatic C10-12, were noted from sample US18 Side Tank. Criteria (GAC) exceedances of Aliphatic C6-C8, Aliphatic C8-C10 and Aliphatic C10-12, were noted from sample US18 Tank Base. The exceedances were encountered within surrounding soil strata described as light brown to dark grey soft to firm clay. The exceedances were encountered within tank base material noted as coarse rounded gravel with a strong hydrocarbon odour.

Initial KDC remedial works excavated concrete and soil, exposing the extent of the tank perimeter. The top of the tank was then pierced utilising cold cutting with suitable fire suppression techniques. KDC syphoned approximately 1m^3 of petrol contaminated water into an intermediate bulk container, which was in turn emptied by a vacuum water tanker and removed from site. The remaining void of the tank had previously been backfilled with sand upon past decommissioning.

KDC removed the upper area of the tank, again using cold cutting and fire suppression techniques and excavated approximately 47 tonnes of contaminated sand material into six damp proof membrane lined skips and one eight wheeled tipper truck. The skips and contaminated sand were removed from site. The remaining steel body of the tank was dismantled by cold cutting and scrapped.

The remedial excavation was extended laterally east, south and west and vertically from the petrol tanks area until no further evidence of hydrocarbon contamination was present. KDC removed the concrete petrol tank base to gain access to underlying contaminated soils. The excavation depth ranged between 3.4 and 3.5mbgl.

Validation samples were collected from the side and base upon removal of the contaminated materials and were tested for TPH CWG. Dewatering was required within the excavation in order to collect dry base validation samples and complete effective backfilling. The excavation void was backfilled with virgin Type 1 aggregate import material.

Further details regarding the excavation are included within Table 23.

6.2.2 US46

TPH CWG risk assessment criteria (GAC) exceedances of Aliphatic C8-C10, Aliphatic C10-12, Aromatic C10-12, Aromatic C12-16 and Aromatic C16-21 were noted from sample US46 Side 1, collected during the underground service investigation trial pitting exercise. The exceedance was encountered within pea gravel pipe bedding surrounding a redundant surface water drain.

Initial KDC remedial works excavated an area of 5m x 5m lateral extension, to a depth of 1.1mbgl from the US46 location. However, visual and olfactory evidence of hydrocarbon contamination noted within soils surrounding additional manholes, pipes and services uncovered during the remedial works resulted in a requirement to extend the excavations laterally and vertically in extent. The excavation was extended laterally east, south and west and vertically until no further evidence of hydrocarbon contamination was present. The excavation depth ranged between 1.4 and 2.7mbgl.

KDC removed five pipe runs and four concrete manhole chambers during the US46 contamination dig to gain access to and removal of contaminated pipe bedding and surrounding soils. KDC also removed areas of a tarmac road running parallel along the northern edge of the excavation to gain access to underlying contaminated soils.

Dewatering was required within the excavation in order to collect dry base validation samples.

Validation samples were collected from the side and base upon removal of the contaminated materials and were tested for TPH CWG.

Overburden 1, 2 and 3 samples from three stockpiles of excavated material respectively, were collected and analysed for the full Horsham suite of analysis. Overburden 3 failed the risk assessment criteria and was removed from site. The excavation was partially backfilled using Overburden 1 and 2 material. The remaining excavation void was backfilled with virgin Type 1 aggregate import material.

Further details regarding the excavation are included within Table 23.

Table 23: Further Excavation Extents

*This figure includes the petrol tank sand (35.12 tonnes)

Excavation ID	Start - End Date (incl. backfilling)	Area (m^2)	Depth Range (m)	Soil Off Site (tonnes)	Number of Times Excavation Purged	Soil Treatment/ Disposal Facility
US46	26/10/2016 – 17/11/2016	239.5	1.4-2.7	354.52	N/A	Biogenie - Redhill
US18	07/11/2016 – 22/11/2016	58.4	3.4-3.5	632.10*	N/A	Biogenie - Redhill

6.3 Statistical Approach

6.3.1 Data Analysis

Further to the GQRA carried out in section 6, it was considered appropriate to carry out further statistical analysis of the populations, where GAC had been exceeded to determine suitability for use in a planning scenario.

The data has then been visually examined with reference to Figures 2 to 3, borehole and trial pit logs as well as KDC's knowledge of the site history, to determine if there is any obvious spatial correlation of contaminants. A spatial correlation exists when contaminant concentrations are in a structured pattern such that contamination is distributed in particular areas, with hot-spots of very high concentrations and gradually decreasing concentration with distance from each hot-spot. Spatially correlated data are usually the result of a liquid spill or leak from a point source and organic chemicals are frequently seen in this type of pattern. Where the data appears to have high concentrations distributed at random amongst low concentrations throughout the site it is said to be non-spatially correlated. This type of pattern is usually seen with contaminants that have been deposited in soil at random with no point source.

Where contaminant concentrations are distributed randomly across the site (including with depth) then the statistical analysis has included all of data, which makes the following assumptions about receptor exposure:

- The sampling was non-biased
- Any concentration, within the range and frequency distribution for a particular contaminant, could be detected anywhere on the site
- The receptor moves at random within the exposure area over the exposure duration

The data set has been considered as a whole, given the lack of master planning design level known at this time. This makes the assumption that the concentration of the contaminant decreases with distance from the highest concentration points.

The statistical analysis is based on the guidance contained the CIEH/CL:AIRE publication (May 2008), *Comparing Soil Contamination Data with a Critical Concentration*.

6.3.2 Non-Detects

A significant number of non-detects were identified in in the data set, greater than 10-15% of population. As per CL:AIRE (2008), the non-detect data was substituted for that Method Detection Limit (MDL) as the concentration.

6.3.3 Outliers

Using the ESI Contaminated Land Statistic Calculator V2 programme, outliers were removed from the data set, where the outlier test (Grubbs test) could be considered applicable. This applied to three sample results in the Aliphatic 10-12 data set – TP1 cont black, US18 tank bottom, US46 Side 1. TP1 Cont black was removed from the site. These results were then excluded from the data set and further statistics run on the 'cleaned' data. Where the outlier test applicability was deemed "not applicable", for either normal or lognormal data, outliers were not excluded.

6.3.4 Normality Tests

The distribution of the data was automatically assessed by the ESI stats programme using the Shapiro-Wilk normality test for between 3 and 50 results, the Shapiro-Francia test2 is used from between 51 and 99 results and the Correlation Test3 is used from between 100 and 500 results. The significance level was varied between 5% and 1% to determine the normality. In altering the significance level to 1% for the AliC10-12 population the data was considered to be normally distributed.

Due to the significant number of non-detects many of the populations were deemed to be non-normal, as supported in the histograms showing dominance in the 0-0.5 banding of "measured value" axis.

6.3.5 Testing the Hypothesis

All soil data calculations for the site have been assessed assuming a planning scenario to demonstrate "suitability for use". The key question in this instance is:

Is there sufficient evidence that the true mean concentration of the contaminant is less than the critical concentration?

The Null Hypothesis is therefore that the true mean concentration (95% Upper Confidence Limit of the mean or 95% UCL) is greater than or equal to the critical concentration (i.e. SSAC). In other words the land in question may be considered as contaminated land and further investigation and/or remediation may be required to bring the land into a suitable state for redevelopment.

The Alternative Hypothesis is that the true mean concentration is less than the critical concentration. In other words the land in question would not be considered as contaminated land and is suitable for use.

The assessment has been undertaken at the 95% confidence level on the basis that if the Null Hypothesis is rejected with a high degree of confidence, the developer has a high level of confidence that the land is "suitable for use".

Where data are considered to be normally distributed the one sample t-test has been selected as an appropriate statistical test. This test assumes data are identically and independently distributed and come from an appropriate normally distributed population. Where there is good evidence that the dataset departs significantly from normality the one-sided Chebychev Theorem has been used as an alternative appropriate statistical test.

Where statistical analysis has been carried out, individual statistical output summaries for each contaminant noted to exceed relevant SSAC are provided in the relevant section and full spreadsheets are provided within Appendix Q.

Table 24 indicates the results of the significance testing.

Table 24: Summary of Planning Regime Null Hypothesis.

Contaminant of Concern	Evidence against Null Hypothesis	Significance Test Result	Outcome
Ali C6-C8	50%	Not enough evidence	Action required *
Ali C8-10	0%	$\mu \geq Cc$	Action required *
Ali C10-12	3%	$\mu \geq Cc$	Action required *

Contaminant of Concern	Evidence against Null Hypothesis	Significance Test Result	Outcome
Aro C10-12	14%	μ≥Cc	Action required *
AroC10-12	2%	μ≥Cc	Action required *
Aro C12-16	2%	μ≥Cc	Action required *
AroC16-21	95%	μ<Cc	Suitable for use
Arsenic	100%	μ<Cc	Suitable for use
Copper	100%	μ<Cc	Suitable for use
Lead	99%	μ<Cc	Suitable for use
Benzo(a)anthracene	96%	μ<Cc	Suitable for use
Benzo(a)pyrene	0%	μ≥Cc	Suitable for use
Indeno(ghi)perylene	99%	μ<Cc	Suitable for use
Benzo(b)fluoranthene	99%	μ<Cc	Suitable for use

Where μ is the true mean concentration of the contaminant and Cc is the critical concentration i.e. SSAC.

*action required could take the form of collecting further data and rerunning the significance test, review of critical concentration exposure scenario and basic CLEA mode exposure scenario, or undertaking remediation on a precautionary basis.

6.4 Review of CLEA Exposure Scenario

6.4.1 GQRA Exposure Scenario

The generic GQRA carried out as part of the REP 001 assessment was based on the following parameters:

- Predominant soil type – sand, chosen to included granular made ground fractions.
- Depth of contamination below building 65cm – default CLEA v1.07 setting
- Thickness of contamination – 200cm – default CLEA v1.07
- Organic matter – 0.48 for made ground

6.4.2 DQRA Exposure Scenario

Following review of the logs, consideration was given to refining the CLEA exposure model for the contaminants of concern where $\mu \geq Cc$.

The following table details the changes to the default settings used to generate site specific DQRA exposure models particularly for deep cohesive soils or where vapour sources where confined to relatively thin horizon, e.g. pipe bedding. Input and outputs of the advanced mode CLEA models are included in Appendix R. The additive risk from hydrocarbons has been re-assessed based on the DQRA SSAC and the hazard quotients revised, as per Appendix S.

Table 25: DQRA Inputs

Exploratory Hole	Depth of Contamination (cm)	Thickness of Source (cm)	Soil Type	Organic Matter
TP37	250	200	CLAY	0.2
US07	120	40	SAND	0.48
US16	160	20	CLAY	0.2
US29	120	30	SAND	0.48
US33	50	150	SAND	0.48
TP3 (1.4-1.8)	140	40	Sandy clayey loam	0.48
TP67	120	40	SAND	0.48
Side 1H	130	20	SAND	0.48

Exploratory Hole	Depth of Contamination (cm)	Thickness of Source (cm)	Soil Type	Organic Matter
TP16 OB0-0.3	100	30	SAND	0.48
I1	40	60	Sandy clayey loam	0.48

6.4.3 DQRA results

The following recommendations were made based on a review of the DQRA Site Specific Assessment Criteria (SSAC) and the returned concentrations, as per Table 26 below.

Table 26: Recommendations for Further Remedial Actions

Location	**Depth (m)**	**Contaminants - Pathway**	**Recommended Remedial Action**
Side 2G	0.3-1.5	Additive TPH -ORAL	Cap
Side I1	0.3-1.5	Additive TPH -ORAL	Cap
TP16 overburden	0-0.3, used as backfill at 1m bgl*	Additive TPH - INHALATION	Excavate
TP29	0.30-0.80	Benzo(a)pyrene - ORAL	Cap
TP3	0-1	Additive TPH -ORAL	Cap
TP3 Side 3	0.9-1.4	Additive TPH -ORAL	Cap
TP39	0.30-0.60	Benzo(a)pyrene - ORAL	Cap
TP42	0.25-0.80	Benzo(a)pyrene - ORAL	Cap
TP46	0-2.2	Additive TPH -ORAL	Cap
TP47	0.30-0.80	Benzo(a)pyrene - ORAL	Cap
TP52	0-0.4;0.9-1.2	Additive TPH - INHALATION	Excavate
TP54	0.15-0.70	Benzo(a)pyrene - ORAL	Cap
TP58	0.5-0.8	Additive TPH -ORAL	Cap
TPI1	0.4-1	Additive TPH - INHALATION	Excavate
TP-I2	0.50	Benzo(a)pyrene - ORAL	Cap
US07 Side	1.20-1.60	Ali C10-C12 - INHALATION	Excavate

Location	Depth (m)	Contaminants - Pathway	Recommended Remedial Action
US07 Side	1.20-1.60	Additive TPH - INHALATION	Excavate
US33 BASE	1.1-1.6	Ali C10-C12 - INHALATION	Excavate
US33 BASE	1.1-1.6	Additive TPH - INHALATION	Excavate
US50-Side	0.9-1.3	Additive TPH -ORAL	Cap

*Material from TP16OB, initially originating from 0-0.3mbgl, was used as backfill at 1m bgl. The revised model indicated a risk still to be present at 1m bgl.

The results of the DQRA indicated that no further excavation works were required at the following locations:

- TP37 Side 2A and TP37 Side 4B
- TP3 B 17 ADD
- TP3 CONC BASE
- US29 Base 1 1.2m
- TP67 1.2-1.6m
- Side 1H 1.3-1.5m
- TP I1 0.4-1.0m

6.5 Further Excavations- US07, US25, US33, TP52, TP16OB

6.5.1 US07

Exceedance of both the additive and individual (aliphatic band C10-12) TPHs inhalation risk assessment criteria (GAC) was identified for the US07 'Side' soil sample, collected between 1.2 and 1.6mbgl and described as dark sand material (possibly old pipe backfill) with a slight hydrocarbon odour.

Remedial works the excavation of a 5m x 5m lateral extension area, which was centred at the original US07 pin location and excavated to a depth of 1.8mbgl to remove the suspect contamination.

Validation samples were collected from the side and base, upon removal of the contaminated materials and were tested for TPH CWG. Overburden samples were collected and analysed for the full Horsham suite of analysis.

The excavation was backfilled with quarried Type 1 import material up to a depth of 0.5mbgl and with the tested overburden from 0.5 to1.8mbgl.

Further details regarding the excavation are included within Table 27.

6.5.2 US25

Exceedance of the TPH CWG risk assessment criteria (GAC) for the Aromatic band C21-35 was noted from the sample US25 'Side', collected between 1.2 and 1.4mbgl. The contaminated material was described as black gravel and possible fine ashes and was noted to be present along the eastern side of the decommissioned underground service duct.

Remedial works were aimed to selectively remove the contaminated material along the side of the service duct. The excavation was progressed, laterally, approx. 9.5m northeast and 17.5m southwest of the original US25 pin location, until no visual evidence of the contaminated ashes and gravel were encountered. The excavation depth ranged between 1.9 and 2.1mbgl.

Validation samples were collected from the side and base upon removal of the contaminated materials and were tested for TPH CWG. An overburden sample was collected from 1-2.1mbgl and analysed for the full Horsham suite of analysis.

The excavation was backfilled using the tested overburden material available.

Further details regarding the excavation are included within Table 27.

6.5.3 TP 52

Exceedance of the additive TPH inhalation risk assessment criteria (GAC) was identified for the soil samples collected within 0-0.4mbgl and 0.9-1.2mbgl strata.

Remedial works undertaken by KDC involved the excavation of a 5m x 5m later al extension area, centred at the original TP52 pin location and excavated to a depth of 1.3mbgl.

Validation samples were collected from the side and base, upon removal of the contaminated materials and tested for TPH CWG.

The excavation was completely backfilled with quarried Type 1 import material.

Further details regarding the excavation are included within Table 27.

6.5.4 US33

Exceedance of both the additive and individual (aliphatic band C10-12) TPHs inhalation risk assessment criteria (GAC) was noted for the sample US33 'Base' , collected form the gravel pipe bedding, at a depth of 1.1-1.6mbgl, where visual and olfactory evidence of hydrocarbon contamination were noted.

Remedial works involved the removal of the hydrocarbon impacted soils, until no further visual and/or olfactory evidence of contamination were noticed. The excavation, characterised by an irregular shape, was progressed laterally 3.2m to the north, 8.5m to the south and some 11.5m to the east of the original US33 pin location. The excavation depth ranged between 1.7-2.4mbgl.

As part of the remedial works, a concrete manhole chamber and related redundant pipelines were removed to allow access to surrounding contaminated soils.

Validation samples were collected from the side and base, upon removal of the contaminated materials and were tested for TPH CWG. Overburden samples were collected and analysed for the full Horsham suite of analysis.

The excavation was backfilled with quarried Type 1 import material up to a depth of 0.5mbgl and with the tested overburden from 0.5 to1.7-2.4mbgl.

Further details regarding the excavation are included within Table 27.

6.5.5 TP16 OB

Trial pit TP16 exceedances of Aliphatic C5-6 and lead GAC were noted from 0.3-1.0mbgl in the previous KDC site investigation report. The exceedance was encountered within a stratum described as grey sandy gravel of mixed lithology with occasional cobbles (mainly comprising of crushed concrete, bricks and stones).

KDC excavated an area of 5m x 5m to a depth of 1.0mbgl, and allowed for the excavation, stockpiling and testing of the overburden (0-0.3mbgl) for potential re-use.

Visual and olfactory evidence of contamination was not evident when reaching the extent of the 25m^2 excavation. Validation samples were collected from the side and base upon removal of the contaminated materials (5 samples in total) and were tested for TPH CWG and Lead, with all passing the site criteria. One sample had been allowed for the testing of the overburden.

The overburden sample failed the risk assessment criteria and was removed from site. The remaining excavation void was backfilled with virgin Type 1 aggregate import material.

Further details regarding the excavation are included within Table 27.

Table 27: Further Excavations – US07, US25, US33, TP52, TP16OB

Excavation ID	Start - End Date (incl. backfilling)	Area (m^2)	Depth Range (m)	Soil Off Site (tonnes)	Number of Times Excavation purged	Soil Treatment / Disposal Facility
US25	25/10/2016-27/10/2016	42.4	1.2-1.4	15.6	N/A	Biogenie - Redhill
TP52	8/11/2016 – 14/11/2016	25	1.3	50.68	N/A	Biogenie - Redhill
US33	9/11/2016 – 16/11/2016	71.7	1.7-2.4	168.44	N/A	Biogenie - Redhill

Excavation ID	Start - End Date (incl. backfilling)	Area (m^2)	Depth Range (m)	Soil Off Site (tonnes)	Number of Times Excavation purged	Soil Treatment / Disposal Facility
US07	14/11/2016 – 21/11/2016	25	1.8	73.48	N/A	Biogenie - Redhill
TP16 OB	04/08/2016 - 04/08/2016	25	0-1.0	78.82	N/A	Biogenie - Redhill

6.6 Validation results

Validation samples were taken from the additional excavations detailed in section 6.2 and 6.5.

A review of the validation results against the GACs indicated failures at the locations detailed in Table 28.

Table 28: Validation Results GAC Review

Location	Depth (mbgl)	Contaminant - Pathway
US46 BASE 9	1.70	Additive TPH - INHALATION
US 46 SIDE 4D	1.0-2.0	Additive TPH - INHALATION
US 46 SIDE 3B	0.9-1.50	Additive TPH - INHALATION
US 46 OVERBURDEN 2	-	Additive TPH -ORAL
US46 OVERBURDEN 3	-	Ali C10-C12 and Additive TPH - INHALATION
US46 SIDE 2D	1.10-1.80	Additive TPH - INHALATION
US 46 SIDE 1H	0.5 – 1.0	Aro 21-35 and Additive TPH - ORAL
US25 SIDE3A	1.50-2.00	Ali C8-C10 and Additive TPH - INHALATION
US25 BLUE MATERIAL	1.80	Additive TPH - INHALATION

Location	Depth (mbgl)	Contaminant - Pathway
US33 OVERBURDEN	0-1.7	Benzo(b)fluoranthene - ORAL
TP52 SIDE3	0.00-0.50	Additive TPH - INHALATION
US18 SIDE 3A	1.90-3.00	Ali C6-C8, Ali C8-C10 and Additive TPH - INHALATION
US33 OVERBURDEN	0.00-2.50	Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene - ORAL
US18 SIDE 3B	1.7-2.3	Additive TPH - INHALATION
US07 OVERBURDEN	0-1.2	Additive TPH - INHALATION

6.6.1 Validation DQRA

The CLEA exposure parameters were revised to take account of soil type, depth, horizon thickness and SOM; SSAC were generated based on the following assumptions, and additive TPH Hazard quotients revised. Table 29 below details the non-default inputs.

Table 29: Validation Sample DQRA Inputs

Exploratory Hole	Depth of Contamination (cm)	Thickness of Source (cm)	Soil Type	Organic Matter
US46 Base 9*	170	200	Sandy clayey loam	0.48
US46Side 4D/ Side 2D	100	200	Sandy clayey loam	0.48
US46 side 1H	50	40	Sandy clayey loam	0.48
TP52 Side 3	0	50	SAND	0.48

*US46 Base 9 scenario SSAC were used for the following exploratory holes as the exposure scenario was deemed to be the same:

- US25Side3A
- US25 Blue Material
- US18 Side 3B
- US18 Side 3A

Note US 46 overburden 2, and US 46 Overburden 3 have been removed from site; therefore no further excavation in these areas was required.

6.6.2 Validation DQRA Results

The results of the validation DQRA assessment indicated failures at:

- US33 overburden - 0-1.7mbgl
- US33 overburden - 0-2.5mbgl
- US07 overburden - 0-1.2mbg

6.6.3 Validation of Further Works

A subsequent CLEA model was generated to determine the affect if the near surface soils (0-0.5mbgl) were excavated and replaced with clean cover. The table below details the no-default parameters. Input and result sheets along with additive TPH risk summary sheets are included in Appendices R and S, respectively.

Table 30: Further validation DQRA

Exploratory Hole	Depth of Contamination (cm)	Thickness of Source (cm)	Soil Type	Organic Matter
US33OB/ US07 OB with 500mm clean cover	50	200	SAND	0.48

Material at depth i.e. >0.5m in these locations met the SSAC. Therefore the following recommendation was made to excavate 0-0.5mbgl in these locations and import clean cover. No further validation was considered necessary.

6.7 Summary

A summary of the residual risks on the site following the remedial works is detailed in Section 7.

7. RESIDUAL RISKS

7.1 Residual Risk

Table 31 details the locations of outstanding residual risks for a residential and commercial end uses. Figures 4 and 5 show these locations.

Table 31: Residual Risks

Location	Depth (m bgl)	Contaminants - Pathway	Recommended Remedial Action Residential	Recommended Remedial Action Commercial
Side 2G	0.3-1.5	Additive TPH -ORAL	Cap	N/A
Side I1	0.3-1.5	Additive TPH -ORAL	Cap	N/A
TP29	0.30-0.80	Benzo(a)pyrene – ORAL; amosite	Cap	Cap
TP3	0-1	Additive TPH -ORAL	Cap	N/A
TP3 Side 3	0.9-1.4	Additive TPH -ORAL	Cap	N/A
TP39	0.30-0.60	Benzo(a)pyrene – ORAL; chrysotile	Cap	Cap
TP42	0.25-0.80	Benzo(a)pyrene - ORAL	Cap	N/A
TP46	0-2.2	Additive TPH -ORAL; Chrysotile	Cap	N/A
TP47	0.30-0.80	Benzo(a)pyrene - ORAL	Cap	N/A
TP54	0.15-0.70	Benzo(a)pyrene - ORAL	Cap	N/A
TP58	0.5-0.8	Additive TPH -ORAL	Cap	N/A
TP-I2	0.5	Benzo(a)pyrene - ORAL	Cap	N/A
US50-Side	0.9-1.3	Additive TPH -ORAL	Cap	N/A
TP29	1.70-2.0	Chrysotile	Cap	Cap
TP29	2.5-3.0	Chrysotile	Cap	Cap
TP30	1.0-1.70	Chrysotile	Cap	Cap

Location	Depth (m bgl)	Contaminants - Pathway	Recommended Remedial Action Residential	Recommended Remedial Action Commercial
TP30	2.0-3.0	Chrysotile	Cap	Cap
TPE1	0.40-0.80	Chrysotile	Cap	Cap
TP39	0.90-1.00	Chrysotile	Cap	Cap
TP18	0.00-0.50	Chrysotile	Cap	Cap
TP58	0.05-0.50	Chrysotile	Cap	Cap
TP52	0.00-0.40	Chrysotile	Cap	Cap
TP52	0.90-1.20	Amosite	Cap	Cap
TP28 - ADD	0.2-1.0	Chrysotile	Cap	Cap

7.2 Revised Conceptual Site Model

7.2.1 Introduction

Following completion of the works the conceptual site model (CSM) has been updated. Based on the existing information, the risk assessment outcomes, the likelihood of a pollutant linkage being realised (source, pathway, receptor) and the significance of the risks to human health, the water environment and property was assessed based on the following categories:

- **Green** – based on available information, the likelihood of a pollutant linkage being realised is assessed as unlikely. Significant possibility of significant harm to human health, property and/or a significant possibility of pollution to the water environment has not been identified

- **Amber** – based on available information, the likelihood of a pollutant linkage being realised is assessed as possible. However, there is insufficient information to confirm this observation and further action or assessment may be required, to assess the significance of these observations

- **Red** – based on available information, the likelihood of a pollutant linkage being realised is assessed as likely. Significant possibility of significant harm to human health, property and/or a significant possibility of pollution to the water environment is likely to be present. Further actions or assessment are likely to be required to assess the significance of these observations and/or to break the pollutant linkage. Table 32 shows the Revised Conceptual Site Model.

7.2.2 Uncertainties and Limitations

The investigation, remediation and subsequent monitoring was limited in its nature, duration and extent (spatial and vertical). Its purpose was to identify potentially significant issues across the site. Further soil gas monitoring will be required in order to fully characterise the gas regime on site. Additionally, should site levels change significantly through a cut in profile, further remediation may be required.

Table 32: Revised Conceptual Site Model.

Potential Source	Potential Pathway	Potential Receptor	Quantitative Risk Assessment of Potential Pollutant Linkages	Pollutant Linkages Rating	Recommended Action
Ground contamination associated with fill material and historical land use (TPH and PAHs) and confirmed during site investigation	Dermal contact and ingestion from exposed soils	Construction workers	TPHs were detected at elevated concentrations that could pose a risk. Construction workers are likely to come into contact with these materials during excavations associated with construction works.	Red	During any ground disturbance works operatives should wear suitable PPE to protect from dermal contact with contaminants.
		Future site users – residential and commercial	<u>Residential End Use</u> Benzo(a)pyrene concentrations that could pose a risk through an ORAL pathway were found at TP29 (0.30-0.80m bgl), TP39 (0.30-0.60m bgl), TP42 (0.25-0.80m bgl), TP47 (0.30-0.80m bgl), TP54 (0.15-0.70m bgl) and TPI2 (0.5m bgl). Additive TPH concentrations that could pose a risk through an ORAL pathway were at locations Side 2G (0.3-1.5m bgl), Side 1I (0.3-1.5m bgl), TP3 (0-1.0m bgl), TP3 Side 3 (0.9-1.4m bgl), TP46 (0-2.2m bgl), TP58 (0.5-0.8m bgl) and US 50 Side (0.9-1.3m bgl).	Red	Capping with hardstanding.

Potential Source	Potential Pathway	Potential Receptor	Quantitative Risk Assessment of Potential Pollutant Linkages	Pollutant Linkages Rating	Recommended Action
		Future site users - commercial	Commercial End Use No exceedances.	Green	No remediation / mitigation measures required.
	Inhalation of windblown dust	Construction workers	TPHs and PAHs were detected at concentrations exceeding the relevant GAC. Risk to human health via the production of dust.	Red	Dust mitigation measure should be adopted during construction including the dampening down of material.
		Future site users	TPHs and PAHs were detected at concentrations exceeding the relevant GAC. Risk to human health via the production of dust.	Red	Capping with hardstanding.
	Exposure to TPH and PAH	Construction workers	TPHs and PAHs were detected at concentrations that could pose a risk. Construction workers could come into contact with these soils.	Amber	Occupational air monitoring should be undertaken.

Potential Source	Potential Pathway	Potential Receptor	Quantitative Risk Assessment of Potential Pollutant Linkages	Pollutant Linkages Rating	Recommended Action
	Leaching of contaminants from made ground into underlying groundwater, which could be abstracted	Future site users	Groundwater failures of RPV for metals (Arsenic, Cadmium, Chromium, Nickel and selenium) were noted at BH4, BH5 and BH7 but were not repeated over multiple rounds.	Green	None
	Leaching of contaminants from made ground, into underlying groundwater, which could migrate offsite	Surface Water	Groundwater failures of EQS were noted for copper, nickel, zinc and fluoranthene across the site on multiple rounds. These are not realised consistently in the leachate results across the site and so there is no pollutant linkage. The model is over-predicting partitioning and the made ground is not considered an active source.	Green	None
Asbestos	Inhalation of fibres	Future site users – residential and commercial	ACM was detected at several locations in low concentrations. Specific consideration should be given to TPE1, TP29, TP39, TP18, TP58, TP52, TP28, TP30 and TP46.	Red	Capping with hardstanding

Potential Source	Potential Pathway	Potential Receptor	Quantitative Risk Assessment of Potential Pollutant Linkages	Pollutant Linkages Rating	Recommended Action
Groundwater underlying the site containing elevated concentrations of contaminants.	Abstraction for consumption	Future site users	Metals exceeded the RPV on several rounds at BH4, BH5 and BH7, with isolated hydrocarbon exceedances across the site. The removal of hydrocarbon contaminated soils, combined with the extensive groundwater pumping regime is likely to have had a positive effect on the groundwater quality. Additionally, given that there are no abstractions within 1km of the site, it is unlikely that groundwater will be abstracted from the made ground aquifer in the near future.	Green	None
Groundwater underlying the site containing elevated concentrations of contaminants.	Migration of contaminants to the surrounding surface water body.	Nearby surface water	The results of the Level 3 groundwater assessment has shown there to be an isolated exceedance of fluoranthene exceeding the acceptance criteria at BH4. This is considered to be a one off occurrence and therefore not a significant risk. Fluoranthene and benzo(a)pyrene exceed the acceptance criteria for the water purged from TP28 – TP46.	Green	None

Potential Source	Potential Pathway	Potential Receptor	Quantitative Risk Assessment of Potential Pollutant Linkages	Pollutant Linkages Rating	Recommended Action
Made ground, methane and carbon dioxide.	Migration into buildings via foundation and/or service runs.	Building explosion risk from methane. Future site users – asphyxiation from carbon dioxide.	Initial rounds show low flow and low methane and carbon dioxide concentrations, further rounds are required to fully characterise the site, depending on the evidence.	Amber	Further monitoring may be required in line with BS8485.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Project Objectives

A 1st phase of intrusive investigation, localised remediation works and data assessment was undertaken. Recommendations were then made in KDC's Phase 2 Environmental Investigation Report (Ref: KDC 01140, July 2016) which outlined that additional further intrusive works, soil and groundwater sampling, detailed quantitative risk assessment (DQRA) and contaminant source removal of certain areas were necessary. These works subsequently undertaken by KDC and have now been reviewed, summarised and assessed, in this current report, to determine if any further remedial action may be necessary prior to the site redevelopment.

8.2 Further works

Additional exploratory works were carried out across the site to: gather more data regarding near surface soil chemistry, in areas previously restricted by access, in areas to ensure good spatial coverage of exploratory holes, adjacent to potential offsite sources, and in the place of former building footprints.

Where the initial GQRA had highlighted failures of acceptance criteria, remedial works were carried out which comprised excavation and soil source removal, and in some locations also supported by removal of groundwater and disposal. Excavations were validated using the GQRA assessment criteria.

8.3 Risk Assessment Outcomes

8.3.1 Risk to Human Health

Statistical analysis of both the additional investigatory data and validation results was required to determine the potential risk to future residential users following failure of generic assessment criteria. The assessment indicated that additional action was required which comprised additional investigation, review of the exposure models or remediation.

A review of the exposure models was carried out varying depth to contamination source and horizon thickness. SSAC were generated and screened against the relevant data. Where exceedances were noted, further remediation and validation was carried out until no SSAC failures remained for inhalation pathways.

Elevated concentrations of PAHs and metals have been found to persist in the near shallow soils at concentration greater than the residential end use GAC. Statistical analysis indicates that only the PAH populations are significant and require further remedial action. This could take the form of a cap to prevent exposure to oral pathways. Soil samples in trial pits TPE1, TP29, TP39, TP18, TP58, TP52, TP28, TP30, and TP46 all reported trace asbestos within the near surface soils (0 – 1m). Although these concentrations are considered to present at low risk, it may not be considered negligible. It is recommended that the material at these locations is capped.

Suitable capping of this material is likely to include covering with hardstanding or chemically suitable material, and possibly including geomembrane.

No significant possibility of significant harm has been identified assuming a commercial end use.

8.3.2 Risk to the groundwater as a resource

The results of the L2 soil assessment indicated that there is a potential for pollution to enter groundwater due to leaching of these chemicals from soil.

Metals exceeded the RPV on several rounds at BH4, BH5 and BH7, with isolated hydrocarbon exceedances across the site. The removal of hydrocarbon contaminated soils, combined with the extensive groundwater pumping regime is likely to have had a positive effect on the groundwater quality. Additionally, given that there are no abstractions within 1km of the site, it is unlikely that groundwater will be abstracted from the made ground aquifer in the near future.

These contaminants are not being repeatedly detected above the RPV in groundwater samples. This is backed up by the lack of RPV leachate exceedances as shown in Table 8. It is likely that the model is being conservative in the partitioning and over predicting leachate concentrations.

8.3.3 Risk to the Surface Water

The results of the L3 soil and groundwater assessments indicate that there is a potential for pollution to controlled waters due to leaching of these chemicals from soil, and lateral migration. However, it is likely that the RTM model is conservative in the partitioning and over predicting leachate concentrations. This is backed up by the limited number of EQS leachate exceedances

There are elevated concentrations of copper, nickel, zinc and fluoranthene within the groundwater across the site on multiple rounds. These contaminants are not seen at elevated concentrations within the leachate assessment, suggesting that the soil source is not acting as an ongoing source of contamination except in isolated locations for fluoranthene and zinc.

As previously stated, there are elevated concentrations of metals and PAHs on site in the groundwater as a result of historical leaching; there are no elevated concentrations in BH6, the up-gradient borehole, therefore the source originated on- site. Following the Level 3 groundwater assessment there are no repeated failures across the site for PAHs and metals; therefore it can be concluded that there is no significant groundwater source on site that could impact an offsite receptor.

8.3.4 Risk Assessment Conclusions

Residual risks persist on the site in the form of trace asbestos fibres in near surface soils, and elevated inorganics and PAHs concentrations, which may cause human health harm in a residential end use. The addition of a suitable cap to the site would mitigate exposure and reduce potential for harm. Should the site levels change as part of any development, the risk assessment should be revisited.

It is concluded that there is a low risk of significant potential for significant harm to underlying groundwater or controlled waters from soils and groundwater on site. There is no requirement considered necessary for any additional remedial measures.

8.4 Recommendations

8.4.1 Cap

The addition of a suitable cap to the site would mitigate exposure and reduce potential for harm from exposure in shallow soils to asbestos, and metals and PAHs, when considering development residential end use. Should the site levels change as part of any development, the risk assessment should be revisited.

8.4.2 Soil Gas

Additional sol gas monitoring and further characterisation of the site may be required should a residual end use be pursued when developing the site. Monitoring should be carried out in accordance with BS 8485: 2015 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.

9. REFERENCES

Phase 1 Desk Study, 'Historical Land Quality Investigations Data Review and Preliminary Risk Assessment' report (Ref: KDC 01140, July 2016).

CL:AIRE, 2016. Control of Asbestos Regulations 2012 - Interpretation for Managing and Working with Asbestos in Soil and Construction and Demolition Materials: Industry guidance

CL:AIRE, London. ISBN 978-1-905046-30-0. Download at www.claire.co.uk/asbestos

DWS referenced within European Directive 98/83/EC the Drinking Water Directive

World Health Organisation (WHO) Guidelines for Drinking Water Quality 1993

England and Wales, The Water Supply (Water Quality) Regulations 2000

UK Technical Advisory Group on the Water Framework Directive Application of Groundwater Standards to regulation 2011