

soiltechnics

environmental and geotechnical consultants

Proposed industrial development
MIPA Paints Ltd
Fulflood Road, Havant

Ground Investigation Report

Cedar Barn, White Lodge, Walgrave, Northamptonshire NN6 9PY

t: 01604 781877 **e:** mail@soiltechnics.net
f: 01604 781007 **w:** www.soiltechnics.net

**Proposed industrial development
Land adjacent to MIPA Paints Limited
Fulflood Road
Havant
PO9 5AX**

GROUND INVESTIGATION REPORT

Soiltechnics Ltd. Cedar Barn, White Lodge, Walgrave, Northampton. NN6 9PY.
Tel: (01604) 781877 Fax: (01604) 781007 E-mail: mail@soiltechnics.net

Report originators

Prepared
by



Georgina Everest B.Sc. (Hons)



Assistant Geo-environmental Engineer, Soiltechnics Limited

Supervised
by



Seb Crolla B.Sc. (Hons), MEnvSc., FGS.



Associate Director, Soiltechnics Limited

Reviewed
by



Stephen Cragg B.Sc (Hons), F.G.S.



Director, Soiltechnics Limited



Aerial photograph of site



Approximate site boundaries are edged in **RED**.

Report status and format

Report section	Principal coverage	Report status	
		Revision	Comments
1	Executive summary		
2	Introduction		
3	Desk study information and site observations		
4	Fieldwork		
5	Ground conditions encountered		
6	Laboratory testing		
7	Engineering assessment		
8	Chemical contamination		
9	Gaseous contamination		
10	Effects of ground conditions on building materials		
11	Classification of waste soils under the Waste Acceptance Criteria		
12	Further investigations		
13	Drawings		

List of drawings

Drawing	Principal coverage	Status	
		Revision	Comments
01	Site location plan		
02	Plan showing existing site features and location of exploratory points		
03	Plan showing site development proposals and location of exploratory points		
04a	Plot summarising standard penetration testing (SPT N-values) by location		
04b	Plot summarising standard penetration testing (SPT N-values) by geology		
05	Plot summarising undrained shear strength data in London Clay		
06a	Plot summarising results of pocket penetrometer determinations by location		
06b	Plot summarising results of pocket penetrometer determinations by geology		
07	Section showing construction of combined water & gas monitoring standpipes installed in boreholes BH01, DTS01b, DTS04 and DTS06		

List of appendices

Appendix	Content
A	Definitions of geotechnical terms used in this report
B	Definitions of geo-environmental terms used in this report
C	Borehole records (cable and tool percussion drilling)
D	Borehole records (driven tube sampling techniques)
E	Dynamic probing records
F	Copies of laboratory test result certificates – classification testing
G	Copies of laboratory test result certificates – concentrations of chemical contaminants
H	Analysis and summary of test data in relation to concentrations of chemical contaminants
I	Conceptual models for chemical contamination
J	Record of in-situ gas monitoring results
K	Landfill waste acceptance criteria – primary classification
L	Landfill waste acceptance criteria – secondary classification
M	Landfill waste acceptance criteria – basic categorisation schedules
N	Copies of statutory undertakers' replies

1 Executive summary

1.1 General

- 1.1.1 We recommend the following executive summary is not read in isolation to the main report which follows.

1.2 Site description, history and development proposals

- 1.2.1 The site is situated in Leigh Park, a mixed residential and commercial/light industrial area at the northern edge of Havant. At the time of our investigation, the site comprised disused open space, surfaced with coarse gravel hardstanding and occasional concrete slabs. Site levels are generally uniform, although levels fall sharply beyond the southern boundary towards the stream channel.
- 1.2.2 A review of historical maps and other records indicates previous uses of the site include a sewage works, household cleaning products manufacture and vehicle service and repair.
- 1.2.3 We understand the scheme will comprise the construction of a 2745m² portal framed storage and distribution facility, with offices at mezzanine level and external hardstandings.

1.3 Ground conditions encountered

- 1.3.1 The exploratory excavations encountered Made Ground overlying the Bognor Sand Member, with the London Clay Formation at depth.
- 1.3.2 Made Ground was encountered to depths of up to 4.5m, with the greatest thicknesses present in the south-east of the site. The Bognor Sand deposits comprised of a mix of loose sands and soft to firm clays to depths of up to 5.7m. The London Clay comprised of stiff becoming very stiff clays.
- 1.3.3 Groundwater is present at shallow depths, apparently confined within the Made Ground.

1.4 Foundation solution

- 1.4.1 Due to the thickness of Made Ground and poor load bearing qualities of the Bognor Sand Member, we recommend a piled foundation solution is adopted.
- 1.4.2 A ground bearing floor slab can be adopted providing subgrade soils are adequately compacted to an end-point specification. We recommend plate bearing testing is undertaken to confirm the required compaction has been achieved.

1.5 Chemical and gaseous contamination

- 1.5.1 The health of site users is at low risk from contaminants in soils at the site.
- 1.5.2 Dissolved metals and hydrocarbons have been detected at concentrations exceeding guideline values in a sample of groundwater. Further investigations are required to determine the nature, extent and source of the contamination.
- 1.5.3 Elevated concentrations of carbon dioxide have been measured during ground gas monitoring. Based on an interim assessment of data, gas protection measures will be required. Monitoring remains ongoing.
- 1.5.4 No radon protection measures are considered necessary at the site.
- 1.5.5 Special precautions for Water Supply Pipes may be required should they be installed within the Made Ground. We recommend provision of our report for the water supplier to determine their requirements based on the ground conditions encountered at the site.

1.6 Landfill classification

- 1.6.1 Made Ground and naturally deposited soils are suitable for disposal as inert waste.

2 Introduction

2.1	Objectives
2.2	Client instructions and confidentiality
2.3	Site location and scheme proposals
2.4	Report format and investigation standards
2.5	Previous reporting
2.6	Status of this report
2.7	Report distribution

2.1 Objectives

- 2.1.1 This report describes a ground investigation carried out for a proposed development at land off Fulford Road, Havant, PO9 5AX.
- 2.1.2 The objective of the ground investigation was to establish ground conditions at the site, sufficient to identify possible foundation solutions for the development and provide parameters necessary for the design and construction of foundations.
- 2.1.3 The investigation included an evaluation of potential chemical and gaseous contamination of the site leading to the production of a risk assessment in relation to contamination.
- 2.1.4 The investigation has also been produced to support a planning application for the site by satisfying National Planning Policies Framework sections 120 and 121 or if the project has the benefit of a planning permission, potentially discharge conditions which relate to ground conditions.

2.2 Client instructions and confidentiality

- 2.2.1 The investigation was carried out in October and November 2016 and reported in December 2016 acting on instructions received from Greenwood Management Services Limited on behalf of our client, MIPA Paints Limited.
- 2.2.2 This report has been prepared for the sole benefit of our above named instructing client, but this report, and its contents, remains the property of Soiltechnics Limited until payment in full of our invoices in connection with production of this report.
- 2.2.3 Our original investigation proposals were outlined in our email to JPP Consulting of 16th August 2016. The investigation generally followed our original investigation proposals. The investigation process was also determined to maintain as far as possible the original investigation budget costs.

2.3 Site location and scheme proposals

- 2.3.1 The National Grid reference for the site is 471414, 108294. A plan showing the location of the site is presented on Drawing 01.
- 2.3.1 We understand the scheme will comprise the construction of a 2745m² portal framed storage and distribution facility, with offices at mezzanine level and external hardstandings.
- 2.3.2 We have received layout drawings of the proposed scheme with the layout presented on Drawing 03.

2.4 Report format and investigation standards

- 2.4.1 Sections 2 to 6 of this report describe the factual aspects of the investigation with Section 7 presenting an engineering assessment of the investigatory data. Section 8 provides a risk assessment of chemical contamination based on readily available historic records, inspection of the soils and laboratory testing. Section 9 provides a similar risk assessment in relation to gaseous contamination with Section 10, a risk assessment relating to construction materials likely to be in contact with the ground. Section 11 provides a classification of waste soils for off-site disposal under the waste acceptance criteria.
- 2.4.2 This investigation integrates both contamination and geotechnical aspects. The investigation was carried out generally, and where practical following the recommendations of BS EN 1997:2 2007 '*Eurocode 7 – Geotechnical Design – Part 2: Ground Investigation and Testing*'. The investigation process also followed the principles of BS10175: 2011 '*Investigation of potentially Contaminated Sites – Code of Practice*'. In view of the client's requirement for rapid implementation of the investigation, the following elements, defined in BS10175, have been completed and incorporated in this report.
- a) Phase I Preliminary investigation (desk study and site reconnaissance)
 - b) Phase II Exploratory and main (intrusive) investigations
- 2.4.3 The extent and result of the preliminary investigation (desk study) is reported in Section 3. Fieldwork combined the exploratory investigation and main investigation stages into one phase with the extent of these works described in Sections 4 and 6 of this report. Any supplementary investigations deemed necessary are identified in Section 12. Section 13 provides information on any remedial strategy and specification if required.

2.5 Previous reporting

2.5.1 This report incorporates and relies on information contained in the following report:

‘Interpretative report on ground investigation at Proposed MIPA Paints site, Fulford Road, Havant’ (Structural Soils, report ref 730438, September 2015).

2.5.2 We understand our Client retains the benefit of this report.

2.6 Status of this report

2.6.1 This report is final based on our current instructions.

2.6.2 This investigation has been carried out and reported based on our understanding of best practice. Improved practices, technology, new information and changes in legislation may necessitate an alteration to the report in whole or part after publication. Hence, should the development commence after expiry of one year from the publication date of this report then we would recommend the report be referred back to Soiltechnics for reassessment. Equally, if the nature of the development changes, Soiltechnics should be advised and a reassessment carried out if considered appropriate.

2.7 Report distribution

2.7.1 This report has been prepared to assist in the design and planning process of the development and normally will require distribution to the following parties, although this list may not be exhaustive:

Table summarising parties likely to require information contained in this report

Party	Reason
Client	For information / reference and cost planning
Developer / Contractor / project manager	To ensure procedures are implemented, programmed and costed
Planning department	Potentially to discharge planning conditions
Environment Agency	If ground controlled waters are affected and obtain approvals to any remediation strategies
Independent inspectors such as Building Control	To ensure procedures are implemented and compliance with building regulations
Project design team	To progress the design
Principal Designer (PD)	To advise in construction risk identification and management under the Construction (design and management) regulations
Waste recycling operators (if appropriate)	For recycling or reducing hazardous properties (if and where appropriate)

Table 2.7

3 Desk study information and site observations

3.1	General
3.2	Description of the site
3.3	Injurious and invasive weeds and asbestos
3.4	History of the site
3.5	Geology and geohydrology of the area
3.6	Landfill and infilled ground
3.7	Radon
3.8	Flood risk
3.9	Enquiries with statutory undertakers
3.10	Enquiries with Local Authority Building Control and Environmental Health Officers

3.1 General

3.1.1 We have carried out a desk study which was limited to a review of the following:

- a) Desk study information presented in the Structural Soils ground investigation report (refer Section 2.5).
- b) Inspection of geological maps produced by the British Geological Survey together with relevant geological memoirs.
- c) Consultation with Statutory Undertakers.
- d) Site reconnaissance.
- e) Other relevant published documents.

3.1.3 The study did not extend to research of meteorological information or consultation with other interested parties such as English Heritage (ancient monuments), Ordnance Survey (survey control points), Planning Authorities or Archaeological Units.

3.2 Description of the site

3.2.1 The site is situated in Leigh Park, a mixed residential and commercial/light industrial area at the northern edge of Havant. The nearest surface watercourse is Riders Lane Stream, the channel of which is located at the site's southern boundary. Riders Lane Stream flows in a south-westerly direction towards the confluence with Hermitage Stream, approximately 900m to the south-west. Local topography generally falls in a southerly direction towards Langstone Harbour.

- 3.2.2 At the time of our investigation, the site comprised disused open space, surfaced with coarse gravel hardstanding and occasional concrete slabs. Site levels are generally uniform, although levels fall sharply beyond the southern boundary towards the stream channel.
- 3.2.3 With the exception of a small brick structure (possible former switch room), no buildings were present on site. The site is bound to the north, east and west by various industrial units with associated hardstandings, most notably a vehicle services warehouse is located to the east.
- 3.2.4 No major vegetation was present on site. To the south large deciduous trees up to 30m in height run parallel to the stream channel.
- 3.2.5 The photographs below detail site conditions at the time of our investigation.



Photograph 1

The south-west of site looking east showing the southern site boundary and alignment of trees in relation to the stream.



Photograph 2

The south east of site looking towards the west.



Photograph 3

The north west of site looking towards the east.



Photograph 4

The south west of site looking towards the west. Note the manhole cover.

- 3.2.6 A plan showing observed site features and location of exploratory points is presented on Drawing 02.

3.3 Injurious and invasive weeds and asbestos

3.3.1 Injurious and invasive weeds

3.3.1.1 The following weeds are controlled under the Weeds Act 1959:

- Common Ragwort
- Spear Thistle
- Creeping or Field Thistle
- Broad leaved Dock
- Curled Dock

3.3.1.2 Whilst it is not an offence to have the above weeds growing on your land, you must:

- Stop them spreading to agricultural land, particularly grazing areas or land used for forage, like silage and hay
- Choose the most appropriate control method for the your site
- Not plant them in the wild

3.3.1.3 Should you allow the spread of these weeds to another parties land, Natural England could serve you with an Enforcement Notice. You can also be prosecuted if you allow animals to suffer by eating these weeds.

3.3.1.4 In addition to the above, you must not plant in the wild or cause certain invasive and non-native plants to grow in the wild as outlined in the Wildlife and Countryside act 1981. It is an offence under section 14(2) of the act to '*plant or otherwise cause to grow in the wild*' any plants listed in schedule 9, part II. This can include moving contaminated soil or plant cuttings. The offence carries a fine or custodial sentence of up to 2 years. The most commonly found invasive, non-native plants include:

- Japanese knotweed
- Giant hogweed
- Himalayan balsam
- Rhododendron ponticum
- New Zealand pigmyweed

3.3.1.5 You are not legally obliged to remove these plants or to control them. However, if you allow Japanese knotweed to spread to another parties land, you could be prosecuted for causing a private nuisance.

3.3.1.6 The presence of such weeds on site may have considerable effects on the cost / timescale in developing the site. Japanese knotweed can cause significant damage to buildings, roads and pavements following development, if untreated prior to development.

3.3.1.7 Our investigations exclude surveys to identify the presence of injurious and invasive weeds. We did not observe any obvious evidence the above species, however, we recommend specialists in the identification and procedures to deal with injurious and invasive weeds are appointed prior to commencement of any works on site.

3.3.2 Asbestos

3.3.2.1 Our investigations exclude surveys to identify the presence or indeed absence of asbestos on site. Where intrusive investigations were undertaken, we did not observe any obvious evidence of potential asbestos containing materials. This information does not constitute a site specific risk assessment and we recommend specialists in the identification and control / disposal of asbestos are appointed prior to commencement of any works on site or, if appropriate, purchase of the site.

3.3.2.2 The presence of asbestos on site may have considerable effects on the cost / timescale in developing the site. There is good guidance in relation to Asbestos available on the Health and Safety Executive (HSE) web site.

3.4 History of the site

3.4.1 The recent history of the site is summarised in the following table: -

Summary description of site history from Ordnance Survey maps		
Date	Onsite	Offsite
1866-1867	Open field with a path intersecting the east of the site in a north-south direction.	The surrounding area is occupied with fields and woodland. Great Copse is located approximately 25m to the north-east of the site. A stream is recorded adjacent to the southern site boundary.
1895-1898	Path no longer recorded.	No significant change.
1907-1914	As above.	No significant change.
1930-1938	As above.	No significant change.
1952	'Sewage Disposal Works'. Filter beds and settling tanks are recorded in the western part of the site.	The sewage works extends approximately 120m to the south-west of site towards Dunsbury Way. Residential development is recorded 150m to the south-west of the site.
1962-1963	'Works'. A large building occupies most of the site area, with smaller buildings adjacent to the southern boundary.	A slope is recorded at the southern site boundary falling towards the stream channel. Two large buildings recorded as 'Depot' and 'Estate office' located either side of Fulford Road are recorded approximately 40m to the west of site. Another large works building is located approximately 50m to the north-west of site. Allotment gardens are recorded approximately 20m to the south-east of the site.
1970-1973	'Factory'. A single building occupies almost the entire site area, and extends for approximately 180m to the north-east. Another, smaller unlabelled building occupies the south-eastern site area.	Further residential development is recorded 100m to the south, east and west of site, and 200m to the north of site.
1991-1993	As above.	No significant change.
1995	Buildings are no longer recorded on the site.	No significant change.
2002-2010	As above.	Works building to the north of site no longer recorded and replaced by residential development.
Table 3.4.1		

3.5 Geology and geohydrology of the area

3.5.1 Geology of the area

3.5.1.1 We have reviewed geological mapping of the produced by the British Geological Survey (BGS) at a scale of 1:50,000. A summary of the recorded geological information for the site is presented in the table below:

Summary of Geology and likely aquifer containing strata					
Strata	Bedrock or superficial	Approximate thickness	Typical soil type	Likely permeability	Aquifer designation
Head Deposits	Superficial	3-6m	Clays, silts, sands and gravels	Marginally permeable	Secondary Undifferentiated
Bognor Sand Member	Bedrock	5-10m	Sands	Marginally permeable	Secondary A
London Clay Formation	Bedrock	<150m	Clays, silts and sands	Effectively impermeable	Unproductive strata

Table 3.5.1

3.5.1.2 Superficial deposits are the youngest geological deposits formed during the Quaternary, which extends back about 2.6 million years. They rest on older deposits or rocks referred to as bedrock. Soil types and assessments of permeability are based on geological memoirs, in combination with our experience of investigations in these soil types.

3.5.1.3 Secondary A aquifers are predominantly permeable layers capable of supporting water supplies at a local rather than strategic scale. In some cases, Secondary A aquifers can form an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

3.5.1.4 Secondary undifferentiated aquifer is a designation used when it is not possible to attribute fully one of either Secondary A or Secondary B, due to the variable nature of the soils. The unit will therefore be a mix of both, which are defined as follows:

- Secondary A can be defined as: Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
- Secondary B can be defined as: layers which may store limited amounts of ground water. These groundwater stores are generally the water bearing parts of former aquifers.

3.5.1.5 Unproductive strata are defined as deposits exhibiting low permeability with negligible significance for water supply or river base flow. Unproductive Strata are generally regarded as not containing groundwater in exploitable quantities.

3.5.2 Water abstractions

3.5.2.1 One active ground water abstraction point is located 1914m to the south of the site with water abstracted for potable water supply by Portsmouth Water Ltd.

3.5.2.2 The site is **not located** within a zone protecting a potable water supply abstracting from a principal aquifer (i.e. a source protection zone).

3.5.3 Coal mining and brine extraction

3.5.3.1 The site is **not recorded** to be within an area affected by past or present coal mining, or minerals worked in association with coal or brine extraction (within the Cheshire Brine Compensation District).

3.5.4 Shallow mining and natural subsidence hazards

3.5.4.1 The British Geological Survey present hazard ratings for shallow mining and natural subsidence hazards. The site has the following ratings;

Table summarising mining and subsidence hazards

Hazard	Rating
Potential for collapsible ground stability hazard	Very low
Potential for compressible ground stability hazard	Negligible
Potential for ground dissolution stability hazard	Negligible
Potential for landslide ground stability hazard	Very low
Potential for running sand ground stability hazard	Low
Potential for shrinking or swelling clay ground stability hazard	Very low

Table 3.5.4

3.5.4.1 In addition to the above hazard ratings, a report completed by Ove Arup and Partners in December 1991, commissioned by the Department of the Environment (DoE) indicates where mining should be borne in mind when considered planning and development of land. The site is **not recorded** as lying in an area of conclusive rock mining as indicated by the report.

3.5.5 Borehole records

3.5.5.1 The British Geological Survey (BGS) retain records of boreholes formed from ground investigations carried out on a nationwide basis. There are some boreholes recorded close to the site and we can obtain records if required.

3.6 Landfill and infilled ground

3.6.1 There are **no recorded** or historical landfill sites within 1000m of the subject site.

3.7 Radon

3.7.1 The Structural Soils report states that no radon protection measures are necessary in the construction of new buildings at the site.

3.8 Flood risk

- 3.8.1 The site is not located within a fluvial or tidal flood plain. The site is not located within an area at risk of surface water flooding.
- 3.8.2 A Flood Risk Assessment previously reported by Enviros Consulting Ltd in 2004 states the site is at risk of flooding during the 1% annual probability flood.
- 3.8.2 It should be noted that this information does not constitute a site specific Flood Risk Assessment (FRA), and a full FRA may be required for the development to support a planning application or satisfy planning conditions.

3.9 Enquiries with statutory undertakers

- 3.9.1 We have contacted the following Statutory Undertakers (SUs) to obtain copies of their records in order to avoid damaging their apparatus during our fieldwork activities: -

- a) BT Openreach Ltd
- b) Scotia Gas Networks
- c) Southern Water
- d) Scottish and Southern Energy (SSE)
- e) Virgin Media
- f) Portsmouth Water

Copies of responses received prior to publication of this report are presented in Appendix N. These records have been obtained solely for the purposes described above. Some of these records have been obtained from the Internet and from our database without contacting the statutory undertaker direct. Occasionally, SU information is recorded on drawings larger than A3, and thus cannot be easily presented in this report. In such cases we will copy the correspondence but not incorporate the drawing in this report, and maintain the records on our office file.

- 3.9.2 In addition, we have visited the Linesearch web site (www.linesearch.org) which provides a report on national grid networks (National Gas and Electricity Transmission Networks). Again a copy of their report is presented in Appendix N.
- 3.9.3 Normally Statutory Undertakers drawings record the approximate location of their services. We recommend further on site investigations be undertaken to confirm the position of the apparatus and thus establish the effect on the proposed development and the necessity or otherwise for the permanent or temporary diversion of the service to allow the construction of the development to safely and successfully proceed.
- 3.9.4 A foul sewer passes through the site in an east-west alignment adjacent to the southern boundary.
- 3.9.5 It should be noted that statutory undertakers' records normally exclude private services.

4 Fieldwork

4.1	General
4.2	Site restrictions
4.3	Light cable percussion boring
4.4	Driven tube sampling
4.5	Dynamic probing
4.6	Sampling strategies

4.1 General

4.1.1 Fieldwork comprised the following activities:-

- Excavation of three exploratory boreholes using cable and tool percussion drilling techniques
- Excavation of six exploratory boreholes formed using driven tube sampling equipment
- Dynamic probing in five locations

4.1.2 A plan of the site showing observed/existing site features and position of exploratory points is presented on Drawing 02. The position of exploratory points relative to site development proposals is presented on Drawing 03. The position of exploratory points shown on these plans is approximate only and confirmation of these positions is subject to dimensional surveys, which is considered outside our brief.

4.1.3 The extent of fieldwork activities and position of exploratory points were determined by Soiltechnics.

4.1.4 Exploratory points were positioned to avoid known locations of underground services, to avoid possible location of proposed foundations but were also positioned to provide a reasonable coverage of the site. Prior to commencement of exploratory excavations an electronic cable locating tool was used to scan the area of the excavation. If we received a response to this equipment then the excavation would be relocated.

4.1.5 All soils exposed in excavations were described in accordance with BS EN ISO 14688 '*Identification and Classification of soil*' and BS EN ISO 14689 '*Identification and classification of rock*'.

4.2 Site restrictions

4.2.1 With the exception of buried services, site features did not restrict our fieldwork activities.

4.3 Light cable and tool percussion boring

- 4.3.1 Boreholes BH01 to BH03 were excavated using light cable percussion boring techniques as described in EN ISO 22475-1:2006 forming 150mm diameter holes. Temporary casing was advanced within the borehole excavation to maintain the stability of the hole. When groundwater was encountered the excavation was temporarily halted to allow for groundwater observations to be made. Following groundwater observations the casing was advanced within the hole and the location/locations of the water strikes recorded. The casing was subsequently advanced to maintain the stability of the borehole and seal off the water to prevent further ingress. Additional records were taken when (and if) the casing produced a seal against water ingress. When obstructions were encountered a chisel was employed to break through the obstruction. Time taken to progress the excavation using the chisel is recorded on the borehole logs.
- 4.3.2 On completion of excavations the boreholes were backfilled with excavated soils compacted using drilling tools.
- 4.3.3 Soil samples for subsequent laboratory determination of concentration of chemical contaminants were taken from 'intact' bulk disturbed samples obtained in the cutting shoe of the drilling rig. A sub sample was obtained discarding soil, which would have been in contact with the drilling rig cutting shoe with the subsamples taken using clean stainless steel equipment. In all cases the stainless steel equipment was cleaned with deionised water between sampling with samples stored in new plastic containers, which were labelled and sealed. If as a consequence of visual or olfactory evidence, a sample was suspected to be contaminated by organic material, the sample was stored in an amber glass jar with a PTFE sealing washer.
- 4.3.4 Bulk soil samples for identification or subsequent 'classification' laboratory testing were taken from borehole cutting equipment. The sample were placed in a plastic bag and subsequently sealed and labelled. Soil samples were obtained under category A to meet laboratory test quality classes 3 to 5 as described in BS EN ISO 22475-1:2006.
- 4.3.5 'Undisturbed' 100mm diameter samples were taken in cohesive soils when considered appropriate using a general-purpose open tube thin walled sampler. These samples were obtained under category B sampling methods to meet quality class 3 and 4 as described in BS EN ISO 22475-1: 2006. The undisturbed sample was obtained in a plastic liner and sealed with wax prior to labelling. The number of blows of the standard driving hammer is required to obtain the sample is recorded on borehole records.

- 4.3.6 Standard Penetration Testing (SPT) was carried out at regular frequencies in the borehole. The test was carried out in accordance with BS EN ISO 22476-3:2005. Details of the test, as required by BS EN ISO 22476-3 are recorded in borehole records. The drive rods were type AW. Samples taken from the open sampler (SPT) were placed in a plastic bag, sealed and labelled. In coarse granular soils, a solid 60° cone may have been used to replace the SPT cutting shoe. This test is reported as SPT(C). A graphical summary of standard penetration testing is presented on Drawing 04a.
- 4.3.7 A pocket penetrometer was used in cohesive soils and is deemed to measure the apparent ultimate bearing capacity of the soil under test. The pocket penetrometer is calibrated in kg/m². The reading can be approximately converted to an equivalent undrained shear strength by multiplying the result by a factor of 50. Tests were carried out on 'intact' samples recovered from the cutting shoe.
- 4.3.8 A graphical summary of pocket penetrometer readings is presented on Drawing 06a.
- 4.3.9 The borehole excavations were formed by drillers who are NVQ Level 2 qualified in Land Drilling under the Construction Awards Alliance CAA with samples relogged by an experienced Geotechnical Engineer.
- 4.3.10 Records of boreholes formed by light cable and tool percussion drilling techniques are presented in Appendix C.
- 4.3.11 A combined gas and groundwater monitoring standpipe was installed in borehole BH01. The standpipe was installed following the recommendations of BS EN ISO 22475-1:2006 *'Geotechnical Investigation and Testing – Sampling methods and groundwater measurements – Part 1: Technical Principles for execution'* and BS8576:2013 *'Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'*. Details of the standpipe installation are recorded on Drawing 07.
- 4.3.12 Water levels in the standpipes have been measured during a return visit to the site. The water level was measured using a measuring tape calibrated in 1mm intervals with an electronic end piece, which emits an alarm sound in contact with water. Water levels are measured from ground levels at the borehole position. Records of water levels are presented in Appendix J.

4.4 Driven tube sampling

- 4.4.1 Boreholes DTS01 to DTS06 were formed using driven tube sampling equipment. Driven tube sampling comprises driving 1m long steel sample tubes which are screw coupled together or coupled to extension rods and fitted with a screw on cutting edge. The sample tubes are of various diameters, generally commencing with 100mm and reducing, with depth, to 50mm and include a disposable plastic liner which is changed between sampling locations in order to limit the risk of cross contamination. On completion of excavation the liner containing the sample is cut open and the soil sample logged by a geo-environmental engineer.
- 4.4.2 Samples for determination concentration of chemical contaminants are taken from samples obtained in the disposable tubes as sub-samples using stainless steel sampling equipment, which is cleaned with de-ionised water.
- 4.4.3 The driven tube sampler obtains samples under category A allowing laboratory test quality classes 3 to 5 as described in BS EN ISO 22475-1:2006.
- 4.4.4 A pocket penetrometer was used in the cohesive soils retrieved from the borehole. This tool is deemed to measure the apparent ultimate bearing capacity of the soil under test. The pocket penetrometer is calibrated in kg/cm^2 . The reading can be approximately converted to an equivalent undrained shear strength by multiplying the results by a factor of 50. The results are reported on borehole records. The pocket penetrometer is not covered by British Standards.
- 4.4.5 A summary of pocket penetrometer results obtained from the cohesive soils retrieved from the boreholes are presented in graphical format on Drawing 06a.
- 4.4.6 Combined gas and groundwater monitoring standpipes were installed in boreholes DTS01b, DTS04 and DTS06. The standpipes were installed following the recommendations of BS EN ISO 22475-1:2006 '*Geotechnical Investigation and Testing – Sampling methods and groundwater measurements – Part 1: Technical Principles for execution*' and BS8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)*'. Details of the standpipe installation are recorded on Drawing 07.
- 4.4.7 Water levels in the standpipes have been measured during a return visit to the site. The water level was measured using a measuring tape calibrated in 1mm intervals with an electronic end piece, which emits an alarm sound in contact with water. water levels are presented in Appendix J.
- 4.4.8 Records of boreholes formed using driven tube sampling techniques are presented in Appendix D.

4.5 Dynamic probing

4.5.1 Dynamic probing was carried out in 5 locations. Dynamic probing consists of driving a 50mm diameter, 90° cone into the ground, via an anvil and extension rods with successive blows of a freefall hammer. The number of blows required to drive the cone each successive 100mm (N10) is recorded.

4.5.2 Dynamic probing was carried out following BS EN ISO 22476-2:2005 and the apparatus used was categorised as 'Super heavy' (DPSH-B) in accordance with the standard.

4.5.3 Dynamic probing results are presented in Appendix E.

4.6 Sampling strategies

4.6.1 Geotechnical

4.6.1.1 In general we adopted a judgemental sampling strategy in relation to geotechnical aspects of the investigation. The location and frequency of sampling was carried out in consideration of the following:

- i) Topography
- ii) Geology (including Made Ground)
- iii) Nature of development proposals

4.6.2 Environmental

4.6.2.1 Details of sampling with respect to contamination issues are described in Section 8.

4.6.3 Sample retention

4.6.3.1 Samples are stored for a period of one month following issue of this report, unless otherwise requested.

5 Ground conditions encountered

5.1	Soils
5.2	Groundwater
5.3	Evidence of contamination
5.4	Obstructions and instability

5.1 Soil

5.1.1 The exploratory excavations encountered a profile of soils considered to be Made Ground overlying the Bognor Sand Member, which in turn overlies the London Clay Formation.

5.1.2 Made Ground was encountered in all locations to depths in the range of 1.2 to 4.5m where the full thickness was proven. Made Ground comprised of a chaotic mixture of brown and grey loose to medium dense sand and gravel and soft to firm clay with frequent cobbles of brick. Made Ground deposits generally became more fine-grained (clay-type) with depth. Gravels consisted of flint, brick, timber, concrete, sandstone, glass and ash.

5.1.3 The Bognor Sand Member was encountered in the majority of locations, with the full thickness proven at depths in the range of 4.2 to 5.7m. The Bognor Sand Member comprised of soft orange brown sandy clay or loose clayey gravelly sand with gravels of flint.

5.1.4 The London Clay Formation was encountered in boreholes BH01, BH02 and BH03 and DTS01b to depths in excess of 20.45m. The London Clay generally comprised of stiff becoming very stiff silty clay. A 0.5m thick layer of claystone was encountered at 8.6m depth in BH01, requiring chiselling to progress the excavation.

5.1.5 The following table summarises the geology encountered:

Table summarising soil types				
Strata	Depth to top (min)	Depth to bottom (max)	Thickness (min to max)	Summary description
Made Ground	-	4.5m*	1.2 – 4.5m*	See paragraph 5.1.2
Bognor Sand Member	1.20m	5.7m	1.6 – 3.5m*	See paragraph 5.1.3
London Clay Formation	4.2m	>20.45m	>16.25m	See paragraph 5.1.4

Table 5.1.5

* Where full thickness proven

5.1.6 With the exception of Made Ground, the investigation generally confirmed published geological records.

5.2 Groundwater

5.2.1 Groundwater inflows were observed in some of the exploratory excavations. A summary of our observations is tabulated below:

Table summarising groundwater observations			
Exploratory point	Date of observation	Depth (m) below ground levels	Observations
BH01	31/10/2016	8.6m	Rising to 4m after 10 minutes, 3.7m after 15 minutes and remaining at 3.7m after 20 minutes.
	08/11/2016 (return monitoring)	1.0m	-
	07/12/2016 (return monitoring)	1.54	-
DTS01b	08/11/2016 (return monitoring)	3.25	-
	07/12/2016 (return monitoring)	2.54	-
DTS04	31/10/2016	1.5m	Measured after completion of borehole, rising to 1.35m after 20 minutes.
	08/11/2016 (return monitoring)	1.65	-
	07/12/2016 (return monitoring)	1.16	-
DTS05	31/10/2016	2.6m	Measured 30 minutes after completion of borehole.
DTS06	08/11/2016 (return monitoring)	Dry	-
	07/12/2016 (return monitoring)	2.02	-

Table 5.2.1

5.2.2 It should be noted that water levels will vary depending generally on recent weather conditions and only long term monitoring of levels in standpipes will provide a measure of seasonal variations in groundwater levels.

5.3 Evidence of contamination

5.3.1 During the excavation of our exploratory points, evidence of potential contamination was identified. A summary of these observations is presented below;

Table summarising contamination observations			
Exploratory point	Depth of contamination	Strata	Description
DTS01b	3.1m – 4.5m	Made Ground	Slight hydrocarbon odour present.
DTS02	1.3m-1.5m	Made Ground	Organic odour present.
DTS04	1.35m	Water	Slight hydrocarbon odour noted within groundwater.
DTS05	2.6m	Water	Very slight TPH odour noted within groundwater.

Table 5.3.1

5.4 Obstructions and instability

5.4.1 The following table summarises obstructions encountered during our exploratory excavations:

Table summarising obstructions and instability observations		
Exploratory point	Depth of obstruction	Description of obstruction and/or instability
BH01	8.7m – 8.9m	Chiselling for 1 hour
DTS01a	1.0m – 1.5m	Terminated due to suspected service from 1.0m to 1.5m. Borehole collapsed to 1.0m depth.
DTS03	1.00	Terminated due to concrete obstruction. Borehole collapsed to 0.8m depth.
DTS05	1.0m – 2.0m	75% recovery due to compression.
DTS06	3.80m	Terminated due to obstruction. Borehole collapsed to 1.85m depth.
Table 5.4.1		

6 Laboratory testing

6.1	Classification and physical testing
6.2	Chemical testing

6.1 Classification and physical testing

6.1.1 Laboratory testing was carried out on samples retrieved from site. The method of testing is recorded on the laboratory test certificate. The following table summarises the classification and physical testing scheduled:

Table summarising classification and physical testing			
Exploratory point	Depth (m)	Soil type	Testing scheduled
BH01	1.0	Made Ground	Sedimentation by hydrometer
	2.7	Bognor Sand Member	Atterberg Limits
	6.7	London Clay Formation	Atterberg Limits
	9.2	London Clay Formation	Undrained Shear Strength, Oedometer Consolidation
	12.2	London Clay Formation	Undrained Shear Strength
	15.2	London Clay Formation	Undrained Shear Strength
	18.2	London Clay Formation	Undrained Shear Strength
BH02	1.0	Made Ground	Atterberg Limits
	3.2	Bognor Sand Member	Atterberg Limits
	5.2	Bognor Sand Member	Atterberg Limits
	8.7	London Clay Formation	Undrained Shear Strength
	11.7	London Clay Formation	Undrained Shear Strength
	14.7	London Clay Formation	Undrained Shear Strength, Oedometer Consolidation
	17.7	London Clay Formation	Undrained Shear Strength
BH03	8.7	London Clay Formation	Undrained Shear Strength, Oedometer Consolidation
	9.2	London Clay Formation	Atterberg Limits
	11.7	London Clay Formation	Undrained Shear Strength
	14.7	London Clay Formation	Undrained Shear Strength
	17.7	London Clay Formation	Undrained Shear Strength
DTS05	2.5	Bognor Sand Member	Sedimentation by hydrometer

Table 6.1.1

6.1.2 Laboratory test certificates are presented in Appendix F.

6.2 Chemical testing

6.2.1 Chemical testing was carried out based on ground conditions and with reference to the contamination Initial Conceptual Model as presented in Section 8. The test methods are recorded on the chemical test certificates. The following table summarises the chemical testing scheduled:

Table summarising chemical testing			
Exploratory point	Depth (m)	Medium/soil type	Testing scheduled (Refer to Appendix B for details)
BH01	0.5	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	2.2	Groundwater	Suite 3, Suite 9, TPH Criteria Working Group (Waters)
	3.2	Bognor Sand Member	Suite 8
	13.7	London Clay Formation	Suite 8
BH02	8.2	London Clay Formation	Suite 8
	17.2	London Clay Formation	Suite 8
BH03	0.5	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	12.2	London Clay Formation	Suite 8
DTS01a	0.1	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	2.3	Made Ground	Organic Matter
DTS01b	3.1	Made Ground	Suite 7
	4.1	Made Ground	Suite 7
DTS02	0.4	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	1.4	Made Ground	Organic Matter
DTS03	0.8-0.9	Made Ground	Suite 8
DTS04	0.4	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	1.15	Made Ground	Organic Matter
	1.35	Groundwater	Suite 3, Suite 9, TPH Criteria Working Group (Waters)
	1.5-1.6	Bognor Sand Member	Suite 8
	1.8	Bognor Sand Member	Suite 7
DTS05	0.6-0.8	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	1.6-1.7	Made Ground	Organic Matter
DTS06	0.2	Made Ground	Asbestos Screening + Free Fibres, Suite 1
	1.1	Made Ground	Suite 8
	1.55	Made Ground	Suite 7
Composite	-	Made Ground	Waste Acceptance Criteria (WAC)
Table 6.2.1			

6.2.2 Laboratory testing was carried out by an independent specialist testing house which operates a quality assurance scheme. Copies of laboratory test result certificates are presented in Appendix G.

7 Engineering assessment

7.1	General description of the development
7.2	Building foundation design and construction
7.3	Influence of trees and other major vegetation
7.4	Ground floor construction
7.5	Service trench excavations
7.6	Infiltration potential
7.7	Pavement foundations

7.1 General description of the development

7.1.1 The following assessments are made on the investigatory data presented in the preceding sections of this report and are made with reference to specific nature of the development. Should scheme proposals change then it may be necessary to review the investigation and report.

7.1.2 We understand the scheme will comprise the construction of a 2745m² portal framed storage and distribution facility, with offices at mezzanine level and external hardstandings.

7.2 Building foundation, design and construction

7.2.1 Definitions of geotechnical terms used in the following paragraphs are provided in Appendix A.

7.2.2 The following factors will present significant constraints to shallow foundations:

- The thickness of the Made Ground (up to 4.5m)
- Instability within excavations in the Made Ground
- The presence of below ground obstructions
- Poor strength characteristics and variable nature of the Bognor Sand deposits

7.2.3 In view of the variable thickness of and apparent variation in the compaction of the near surface Made Ground, in our opinion the Made Ground is incapable of supporting concentrated foundation loads without promoting excessive amounts of total and differential settlements.

7.2.4 The Bognor Sand Member deposits comprise interbedded loose to medium dense coarse-grained material and soft to firm low to medium strength silty clay with variable proportions of sand and gravel. Groundwater is present at shallow depths (<2m). Although the Bognor Sand Member deposits are likely to be a suitable founding stratum, the depth to this layer (up to 3.5m where proven), the presence of shallow groundwater and the instability within the Made Ground means that excavations to construct such foundations will be difficult to successfully achieve.

- 7.2.5 Obstructions were encountered in boreholes DTS03 and DTS06 at depths of 1.0 and 3.8m respectively. It is possible that the obstructions encountered are associated with foundations to former site buildings, although further trial pit investigations would be required to determine the extent of remaining substructures.
- 7.2.6 In our opinion and based on the ground conditions encountered, piled foundations would offer the most practical solution for this site. Piled foundations would transmit structural loads through the Made Ground and Bognor Sand Member to obtain shaft adhesion and end bearing support in the London Clay. The difficulty of driving or boring piles through the underlying soils will need to be considered by any specialist piling company and will affect the method of pile installation. The presence of below ground obstructions will also require consideration.
- 7.2.7 **Pile design and installation**
- 7.2.7.1 The undrained shear strength of undisturbed soil samples taken from the London Clay Formation has been measured in the laboratory. Laboratory and in-situ shear strength determinations in the London Clay are summarised on Drawing 05. Standard penetration test (SPT) N-values have been converted to undrained shear strength following the relationship described in Stroud & Butler (1975), with these values also presented on Drawing 05. The resulting plot can be used to determine shaft adhesion and end bearing support to piles. The adhesion value (α) would be 0.5, following guidance provided in '*Guidance notes for the design of straight shafted bored piles in London Clay*' (2009) produced by the London District Surveyors Association (LDSA),
- 7.2.7.2 We recommend that the design and installation of the piles are determined by a specialist piling contractor who has experience of pile installation in these or similar ground conditions and who may be able to interpret the observed ground conditions in a different and potentially more beneficial manner. We recommend that the specialist piling contractor assumes responsibility for the choice, design and installation of the piles.
- 7.2.7.3 We recommend that piling is carried out following the '*Specification for Piling and Embedded Retaining Walls*' produced by the Institution of Civil Engineers.
- 7.2.7.4 It is likely that a 'piling mat' will have to be constructed in advance of piling operations. This will be designed following the Building Research Establishment publication '*Working Platforms for tracked plant: good practice guide to the design, installation, maintenance and repair of ground supported working platforms*'. We will be pleased to assist in the design and specification of such a platform on further instructions.

7.3 Influence of trees and other major vegetation

- 7.3.1 If a piled foundation will be adopted, foundations will fully penetrate the zone of influence of any nearby trees and as such, no additional deepening would be required to account for the shrinking/ swelling of clay under the footings. If shallow footings are adopted, we recommend that the influence of trees is assessed and foundations are deepened accordingly. A good guide is presented in NHBC Chapter 4.2.

7.4 Ground Floor Construction

- 7.4.1 Ground bearing floor slabs can be adopted at this site located on the Made Ground deposits, but some settlement could be expected (refer paragraph 6.4.4 below). Following completion of excavations to formation levels we recommend the formation is rolled using a heavy roller to identify any soft areas and indeed compact near surface soils which may have been disturbed by excavation processes. Any 'soft' areas will require excavation to locate more stable soils. We recommend a blanket of good quality compacted granular material be placed prior to construction of the floor slabs.
- 7.4.2 We understand the floor slab is not required to support settlement sensitive equipment and will be constructed for general warehouse/retail usage. With reference to 'Concrete industrial ground floors' (Technical Report no. 34 – third edition) produced by the Concrete Society, the modulus of subgrade reaction (k) supporting the floor slab has only a minor effect on the slab design thickness for flexural stresses and does not therefore have to be estimated with great accuracy.
- 7.4.3 The modulus of subgrade reaction is a measure of the elastic properties of near surface soils. Plate bearing tests provide the most accurate measure of elastic modulus and we can carry this out on further instructions. California Bearing Ratio (CBR) test data be converted to an equivalent modulus of subgrade reaction (see Technical Report 34), but CBRs are not a direct measure of modulus. Again, we can carry out CBR testing on further instructions.
- 7.4.4 In addition to elastic deformation of soils estimated from k values, some long-term settlement of the floor slab will occur under applied loads, particularly uniformly distributed loads. We understand that applied loads will typically be in the range of 10-25kN/m², rising to 80kN/m² beneath concentrated racking loads. Assuming a constantly applied uniformly distributed load of say 30kN/m², settlements in the order of 5-10mm could occur within 5 to 10 years. Some differential settlement will occur in the long term where the floor slab is not uniformly loaded. Removal of the Made Ground and replacement with a well compacted (to an end point specification) well graded and durable granular fill would substantially reduce levels of possible settlement
- 7.4.5 Vibrotreatment of the area below the floor slab will increase the density of the near surface deposits and thus reduce levels of settlement.

7.5 Service Trench Excavations

- 7.5.1 It is difficult to predict the stability of trench sides from borehole investigations. Generally we would anticipate a risk of some overbreak/instability in the Made Ground deposits. There is an increasing likelihood of encountering groundwater in excavation >2m depth.
- 7.5.2 We recommend any trench excavation requiring human entry is shored as necessary to conform with current best practice, and accepted by the Health and safety Executive (HSE) and in particular, following guidance provided in the HSE publication 'Health and safety in construction (HSG 150)' www.hse.gov.uk

7.6 Infiltration Potential

- 7.6.1 The Bognor Sand deposits are, in our opinion, effectively impermeable and would not be able to dispose of water using soakaway systems. Coarse grained layers were encountered within the Bognor Sands, although these were sporadic and designing infiltration systems to target these layers would be highly problematic.
- 7.6.2 Made Ground deposits will exhibit a varying degree of permeability and potentially will be able to dispose of stormwater using infiltration systems. Such a method of stormwater disposal does have the following potential drawbacks:
- Water freely/directly discharged into the Made Ground could cause collapse of air voids contained in these deposits, which promotes compaction of the soils around the soakaway causing depression of the general area around the soakaway as well as potentially affecting pipe runs leading to the soakaway.
 - Water freely/directly discharged into soils close to cutting slopes could promote instability of such slopes. The slope falling to the stream at the site's southern boundary would be at potential risk of instability.
 - It would need to be demonstrated to regulators that discharge of water to Made Ground would not result in the creation of pathways for contamination of Rider's Lane Stream.

7.7 Pavement Foundations

- 7.7.1 It is anticipated that the proposed access road and associated hardstanding areas will be located at or about existing ground levels with formation located on Made Ground soils.

- 7.7.2 Equilibrium CBR (California Bearing Ratio) values (with reference to Transport and Road Research Laboratory (TRRL) Report LR1132 '*Structural design of Bituminous Roads*') are derived from knowledge of soil classification data (plasticity index for soils exhibiting cohesion (clay type) and particle size distribution for granular soils), the location of the water table pavement thickness, and weather conditions at the time of construction. It is anticipated that excavations to formation levels will encounter a mixture of both granular and cohesive soils. Granular soils will provide numerically high CBR values, but cohesive soils will typically provide significantly lower values. Assuming an average plasticity index of say 20 for cohesive soils, a low water table, a 'thin' pavement the following equilibrium CBR values are derived for varying construction conditions

Equilibrium CBR values for differing construction conditions		
Poor	Average	Good
CBR = 3%	CBR = 5%	CBR = 6%

Table 7.7.2

- 7.7.3 It is possible to derive the 'insitu' CBR value at formation from undrained shear strength data by applying a conversion factor of 23 (refer TRRL laboratory report LR889). Thus adopting pessimistic undrained shear strength of say 70kN/m² at formation level (based on insitu shear strength measurements) then an equivalent CBR value can be obtained i.e.

$$\text{Insitu CBR} = \text{undrained shear strength} \frac{70}{23} = 3\%$$

- 7.7.4 The 'insitu' CBR derived above, is susceptible to change dependent upon weather conditions during construction. The equilibrium CBR value derived in paragraph 7.7.2 above is an estimate of the CBR value, which will predominate during the life of the pavement. We recommend the insitu **CBR of 3%** derived from shear strength data be utilised for design purposes and reassessed during construction. The fact that the clay subgrade soils are likely to be deemed frost susceptible will probably be the overriding criteria for pavement foundation design purposes. It should also be noted that the thickness of the pavement foundation also relates to the amount and loading from construction traffic, which is discussed in detail in the Transport and Road Research Laboratory (TRRL) Report LR1132 '*Structural design of Bituminous Roads*'.
- 7.7.5 Made Ground deposits at the site exhibit a degree of variation in compactness. Some long term settlement of hardstandings will occur due to consolidation of the Made Ground deposits and from applied loads, particularly uniformly distributed loads. It is difficult to accurately predict levels of settlement, as potentially applied loading patterns are not known. Equally, some differential settlement could occur in the long term, if hardstandings are not uniformly loaded. We suggest that pavements under transient (vehicular) loads are unlikely to generate significant levels of settlement.

- 7.7.6 Once formation levels have been established it is recommended that the formation be trimmed and rolled following current requirements of the Highways Agency Specification for Highways Works (clause 616) (refer www.dft.gov.uk/ha/standards/mchw/vol1) Such a process will identify any soft areas, which we recommend be either excavated out and backfilled with a suitable well compacted material similar to those exposed in the sides of the resulting excavation, or large cobbles of a good quality stone rolled into the formation to stabilise the 'soft' area.
- 7.7.6 The silty nature of the Made Ground soils will render them moisture susceptible with small increases in moisture content giving rise to a rapid loss of support to construction plant. We therefore recommend, as soon as formation is trimmed and rolled, that sub-base is laid in order to avoid deterioration of the subgrade in wet or frosty conditions.

8 Chemical contamination

8.1	Contaminated land, regulations and liabilities
8.2	Objectives and procedures
8.3	Development characterisation and identified receptors
8.4	Identification of pathways
8.5	Assessment of sources of contamination
8.6	Initial conceptual model
8.7	Laboratory testing
8.8	Updated conceptual model
8.9	Remedial action
8.10	Risk assessment summary and recommendations
8.11	Statement with respect to National Planning Policy Framework
8.12	On site monitoring

8.1 Contaminated land regulation and liabilities

8.1.1 Statute

8.1.1.1 Part IIA of the Environment Protection Act 1990 became statute in April 2000. The principal feature of this legislation is that the hazards associated with contaminated land should be evaluated in the context of a site-specific risk based framework. More specifically contaminated land is defined as:

"any land which appears to the local authority in whose area it is situated to be in such a condition, by reasons of substances in, on or under the land, that:

- a) Significant harm is being caused or there is a significant possibility of such harm being caused; or*
- b) Pollution of controlled waters is being or is likely to be caused".*

8.1.1.2 Central to the investigation of contaminated land and the assessment of risks posed by this land is that:

- i) There must be contaminants(s) at concentrations capable of causing health effects (*Sources*).
- ii) There must be a human or environmental receptor present, or one which makes use of the site periodically (*Receptor*); and
- iii) There must be an exposure pathway by which the receptor comes into contact with the environmental contaminant (*Pathway*).

8.1.1.3 In most cases the Act is regulated by Borough or District Councils and their role is as follows:

- i) Inspect their area to identify contaminated land
- ii) Establish responsibilities for remediation of the land

- iii) See that appropriate remediation takes place through agreement with those responsible, or if not possible:
 - by serving a remediation notice, or
 - in certain cases carrying out the works themselves, or
 - in certain cases by other powers
- iv) keep a public register detailing the regulatory action which they have taken

8.1.1.4 For “special” sites the Environment Agency will take over from the Council as regulator. Special sites typically include:-

- Contaminated land which affects controlled water and their quality
- Oil refineries
- Nuclear sites
- Waste management sites

8.1.2 Liabilities under the Act

8.1.2.1 Liability for remediation of contaminated land would be assigned to persons, organisations or businesses if they caused, or knowingly permitted contamination, or if they own or occupy contaminated land in a case where no polluter can be found.

8.1.3 Relevance to predevelopment conditions

8.1.3.1 For current use, Part IIA of the Environmental Protection Act 1990 provides the regulatory regime. The presence of harmful chemicals could provide a ‘source’ in a ‘pollutant linkage’ allowing the regulator (local authority or Environment Agency) to determine if there is a significant possibility of harm being caused to humans, buildings or the environment. Under such circumstances the regulator would determine the land as ‘contaminated’ under the provision of the Act requiring the remediation process to be implemented.

8.1.4 Relevance to planned development

8.1.4.1 The developer is responsible for determining whether land is suitable for a particular development or can be made so by remedial action. In particular, the developer should carry out an adequate investigation to inform a risk assessment to determine:

- a) Whether the land in question is already affected by contamination through source – pathway – receptor pollutant linkages and how those linkages are represented in a conceptual model
- b) Whether the development proposed will create new linkages e.g. new pathways by which existing contaminants might reach existing or proposed receptors and whether it will introduce new vulnerable receptors, and
- c) What action is needed to break those linkages and avoid new ones, deal with any unacceptable risks and enable safe development and future occupancy of the site and neighbouring land?

8.1.4.2 Building control bodies enforce compliance with the Building Regulations. Practical guidance is provided in Approved documents, one of which is Part C, 'Site preparation and resistance to contaminants and moisture' which seeks to protect the health, safety and welfare of people in and around buildings, and includes requirements for protection against harm from chemical contaminants.

8.1.5 Pollution of controlled waters

8.1.5.1 Part IIA of the Environment Protection Act 1990, defines pollution of controlled waters as

'The entry into controlled waters of any poisonous, noxious or polluting matter or any solid waste matter'

8.1.5.2 Paragraphs A36 and A39 of statutory guidance (DETR 2000) further define the basis on which land may be determined to be contaminated land on the basis of pollution of controlled waters.

'Before determining that pollution of controlled waters is being, or likely to be, caused, the Local Authority should be satisfied that a substance is continuing to enter controlled waters, or is likely to enter controlled waters. For this purpose, the local authority should regard something as being likely when they judge it more likely than not to occur'

'Land should not be designated as contaminated land where:

- a) A substance is already present in controlled waters;*
- b) Entry into controlled waters of that substance from the land has ceased, and*
- c) It is not likely that further entry will take place.*

Substances should be regarded as having entered controlled waters where:

- a) They are dissolved or suspended in those waters; or*
- b) If they are immiscible with water, they have direct contact with those waters, or beneath the surface of the waters'*

8.1.5.3 Controlled waters are defined in statute to be:

'territorial waters which extend seawards for 3 miles, coastal waters, inland freshwaters, that is to say, the waters in any relevant lake or pond or of so much of any relevant river or watercourse as is above the freshwater limit, and groundwaters, that is to say, any waters contained in underground strata.'

8.1.6 Further information

8.1.6.1 The above provides a brief outline as regards current statute and planning controls. Further information can be obtained from the Department for the Environment, Food and Rural Affairs (DEFRA) and their Web site www.defra.gov.uk.

8.2 Objectives and procedures

8.2.1 Objectives

8.2.1.1 This report section discusses investigations carried out with respect to chemical contamination issues relating to the site. The investigations were carried out to determine if there are any liabilities with respect to Part IIA of the Environment Protection Act. As stated in Section 2.4.2, the investigation process followed the principles of BS10175: 2011 '*Investigation of potentially contaminated sites – Code of Practice*', with the investigation combining a desk study (preliminary investigation) together with the exploratory and main investigations (refer BS10175: 2011 for an explanation).

8.2.1.2 This section of the report produces '*Conceptual models*' based on investigatory data obtained to date. The conceptual model is constructed by identification of *contaminants* and establishment of feasible *pathways* and *receptors*. The conceptual model allows a *risk assessment* to be derived. Depending upon the outcome of the risk assessment it may be necessary to carry out remediation and/or further investigations with a view to eliminating, reducing or refining the risk of harm being caused to identified receptors. If appropriate, our report will provide recommendations in this respect.

8.2.1.3. Clearly we must consider the current pre-development condition, establishing risks which may require action to render the site safe to all relevant (current) receptors meeting the requirements of current legislation (Part IIA of the Environmental Protection Act 1990)

8.2.1.4 Definition of terms used in the preceding paragraph and subsequent parts of this section of the report are presented in Appendix B.

8.2.2 Procedure to assess risks of chemical contamination

8.2.2.1 For the purposes of presenting this section of this report, we have adopted the following sequence in assessing risks associated with chemical contamination.

Table outlining sequence to assess risk associated with chemical contamination

Conceptual model element	Contributory information	Outcome
Receptor	Development categorisation	Identification of receptors at risk of being harmed Method of analysing test data Criteria for risk assessment modelling
Pathways	Geology and ground conditions Development proposals	Identification of critical pathways from source to receptor
Source	Previous site history Desk study information Site reconnaissance Fieldwork observations	Testing regime Identification of a chemical source Analysis of test data and other evidence

Table 8.2.2

- 8.2.2.2 We have adopted, in general, the procedures described in CIRIA C552 '*Contaminated land risk assessment - a guide to good practice*' in deriving a risk assessment. Initially we have carried out a 'phase 1 assessment' based on desk study information and site reconnaissance, to produce an initial conceptual model and thus a preliminary risk assessment. This model / assessment is then used to target fieldwork activities and laboratory testing, with the results of this part of the investigation used to allow a phase 2 assessment to be produced by updating the conceptual model and refining the risk assessment.

8.3 Development characterisation and identified receptors

8.3.1 Site characterisation

- 8.3.1.1 The nature of the site has a significant influence the likely exposure pathways between potentially contaminated soils and potential receptors. The following table summarises elements which characterise the site based on site observations and desk study information.

Summary of site characteristics		
Element	Source / criteria	Characteristic
Current land use	Observations	Site is currently disused and access restricted by fencing.
Future land use	Advice	Portal framed storage and distribution facility with offices and external hardstanding.
Site history	Desk study	Works and factory until c1995.
Geology	Site investigation	Up to 4.5m of Made Ground overlying 1.6 – 3.5m thickness of Bognor Sand Member, overlying >15m thickness of London Clay.
Ground water	Aquifer potential	Secondary A aquifer within the Bognor Sand Member. Unproductive strata within the London Clay Formation.
	Abstractions	One active groundwater abstraction point 1914m to the south of the site.
	Source protection zone	Site not within source protection zone
Surface waters	Location	Riders Lane Stream located at the southern boundary
	Abstractions	None within 2000m of the site
Table 8.3.1		

8.3.2 Identified receptors

- 8.3.2.1 The principal receptors subject to harm caused by any contamination of the proposed development site are as follows.

Principle Receptor	Detail
Humans	Users of the current site
	End user of the developed site
	Construction operatives and other site investigators
Vegetation	Plants and trees, both before and after development
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)
	Ground waters (used for abstraction or feeding rivers / streams etc)
Building materials	Materials in contact with the ground
Table 5.3.2	

8.3.2.2 This section of the report assesses those receptors listed above. Section 10 provides a risk assessment in relation to building materials.

8.3.3 Human receptors

8.3.3.1 The Contaminated Land Exposure Assessment (CLEA) model can be used to derive guideline values, against which land quality data can be compared to allow an assessment of the likely impacts of soil contamination on humans. The parameters used within the model can be chosen to allow guideline values to be derived for a variety of land uses and exposure pathways. For example, a construction worker is likely to be exposed in different ways and for different durations than an adult in a residential setting.

8.3.3.2 The site is currently disused and secured from access. A current site user is therefore not considered to be present. Following completion of the proposed development, the critical site user (receptor) will be an adult. This criterion has been used in the conceptual model for the current and future site use. Our assessment also considers construction operatives as adult receptors.

8.3.4 Vegetation receptors

8.3.4.1 Soil contaminants can have an adverse effect on plants if they are present at sufficient concentrations. The effects of phytotoxic contaminations include growth inhibition, interference with natural processes within the plant and nutrient deficiencies.

8.3.4.2 Vegetation directly on site is sparse and low lying. Off-site dense vegetation covers the entire southern boundary of the site along the banks of the tributary stream. Although such vegetation is strictly not on site it remains receptive to any changes or developments.

8.3.5 Water receptors

8.3.5.1 The Bognor Sand Member deposits underling the site are designated a Secondary A aquifer. Groundwater is therefore considered to be a potential sensitive receptor.

8.3.5.2 The channel of Riders Lane Stream is located adjacent to the site's southern boundary. This is considered to be a potential sensitive surface water receptor.

8.3.6 Summary of identified receptors

8.3.6.1 Based on the above assessments, the following table summarises identified and critical receptors.

Table summarising identified (viable) receptors				
Principle Receptor	Detail	Viable and critical receptors		
		Viability and justification		Critical receptor
Humans	Users of the current site	No	Site is currently disused and access restricted	-
	End user of the developed site	Yes	Site will be a storage and distribution facility, with associated hardstanding	Adult
	Construction operatives and other site investigators	Yes		Adult
Vegetation	Current site	Yes	Trees at south boundary	Vegetation
	Developed site	Yes	Trees to remain	Vegetation
Controlled waters	Surface waters (Rivers, streams, ponds and above ground reservoirs)	Yes	Riders Lane Stream at site southern boundary	Surface waters
	Groundwaters (used for abstraction or feeding rivers / streams etc)	Yes	Secondary A within Bognor Sand Member	Groundwater
Building materials	Materials in contact with the ground	Yes	Assessed in report section 10	Building materials

Table 8.3.6

8.4 Identification of pathways

8.4.1 Pathways to human receptors

8.4.1.1 Guidance published by the Environment Agency in Science Report SC050021/SR3 'Updated technical background to the CLEA model' provides a detailed assessment of pathways and assessment and human exposure rates to source contaminants. In summary, there are three principal pathway groups for a human receptor:

Table summarising likely pathways	
Principal pathways	Detail
Ingestion through the mouth	Ingestion of air-borne dusts
	Ingestion of soil
	Ingestion of soil attached to vegetables
	Ingestion of home grown vegetables
Inhalation through the nose and mouth.	Inhalation of air-borne dusts
	Inhalation of vapours
Absorption through the skin.	Dermal contact with dust
	Dermal contact with soil

Table 8.4

8.4.1.2 The site is to be developed for a storage and distribution facility with offices. The site is to be covered predominantly by buildings and hardstanding and as such pathways for the exposure of site users to contaminated soils would be severely restricted.

8.4.1.3 Pathways associated with the consumption of home-grown vegetables are not relevant for construction operatives.

8.4.1.4 A summary of our pathway assessment is presented in Section 8.4.4.

8.4.2 Pathways to vegetation

8.4.2.1 Guidance published by the Environment Agency in Science Report SC050021/SR (Evaluation of models for predicting plant uptake of chemicals from soil) provides a detailed assessment of plant uptake pathways. In summary, plants are exposed to contaminants in soils by the following pathways:

- Passive and active uptake by roots.
- Gaseous and particulate deposition to above ground shoots.
- Direct contact between soils and plant tissue.

8.4.2.2 All of the above routes of exposure are considered to be present for vegetation.

8.4.3 Pathways to controlled waters

8.4.3.1 A number of pathways exist for the transport of soil contamination to controlled waters. A summary of these pathways is presented below:

- Percolation of water through contaminated soils.
- Near-surface water run-off through contaminated soils.

8.4.3.2 Under current site conditions, percolation of water through contaminated soils is considered a likely pathway to groundwater. Near surface run-off through contaminated soils is also considered to be a viable pathway to the identified surface water receptor.

8.4.3.3 Following completion of the proposed development, pathways to controlled waters will be significantly limited by the provision of hardstandings and positive drainage.

8.4.4 Summary of identified likely pathways

8.4.4.1 Based on the above assessments, the following table summarises likely pathways of potential chemical contaminants at the site to identified receptors.

Table of likely pathways		
Receptor group	Critical receptor	Pathway
Construction operatives	Adult	Ingestion of air-borne dusts
		Ingestion of soil
		Inhalation of air-borne dusts
		Inhalation of vapours
		Dermal contact with dust
		Dermal contact with soil
Vegetation		Root uptake, deposition to shoots and foliage contact.
Controlled waters	Groundwater	Percolation of water through contaminated soils
	Surface water	Near-surface water run-off through contaminated soils

Table 8.4.4

8.5 Assessment of sources of chemical contamination

8.5.1 Introduction

8.5.1.1 Initially, potential sources of contamination are assessed using the following elements of the investigation process.

- History of the site
- Desk study information
- Site reconnaissance
- Geology
- Fieldwork

8.5.1.2 These elements will dictate a relevant soil/water testing regime to quantify possible risks of any identified contaminative sources which may harm identified receptors.

8.5.2 Source assessment – History of the site

8.5.2.1 The history of the site and its immediate surroundings based on published Ordnance Survey maps is described in Section 3.

8.5.2.2 A review of historical maps indicates the site has been subject to a number of different uses. These can be summarised as follows:

- c1886 to c1952 – open fields
- c1952 to c1962 – sewage works
- c1962 to c1970 – ‘Works’ (type unspecified)
- c1970 to c1993 – ‘Factory’ (type unspecified)
- 2003 onwards – vehicle rental, service and repair

8.5.2.3 We understand that, prior to 2003, the site was occupied by Procter & Gamble, a household cleaning products manufacturing company. After 2003, a garage and MOT centre are recorded. The 'Industry Profiles' published by the Department of the Environment provide information regarding the type of chemical contaminants that may arise from manufacture of household goods and vehicle service and repair. The possibility of potential soil contamination arising from these land uses would be dependent upon the management of potential contaminants within the former industries. At this stage we have assumed there is a risk of each of the potential contaminants impacting soils at the site, and thus there is a potential (and thus a risk) of this chemical source to migrate to the subject site and harm on site receptors.

8.5.3 Source assessment – Desk study information

8.5.3.1 Envirocheck presents a detailed database of environmental information in relation to the site including;

- Pollution incidents
- Landfill sites
- Trading activities

8.5.3.2 Based on the Envirocheck data (refer Appendix O) the site has no recorded history of any pollution events, or trading activities which could generate a source of contamination, or is located in close proximity to a landfill site.

8.5.3.3 Previous investigations at the site discovered petroleum hydrocarbons in soils in the south-eastern area. The contamination was associated with a former fuel storage tank located in this area. Remedial action in the form of excavation and disposal of affected soils was undertaken.

8.5.4 Source assessment – Site reconnaissance

8.5.4.1 A full description of the site and observed adjacent land uses is provided in Section 3 of this report. A plan summarising observations made on site during our site reconnaissance visit is presented on Drawing 02.

8.5.4.2 We did not observe any obvious evidence of any current or recent activities on site which provide a potential source of chemical contamination.

8.5.4.3 MIPA Paints, a paint manufacturing business is located adjacent to the east of the site. Potential contaminants associated with paint manufacture include solvents, inorganic compounds, acids and petroleum hydrocarbons. This adjacent site is considered to represent a potential source of contamination.

8.5.5 Source assessment – Geology

8.5.5.1 The geological map of the area indicates the topography local to the site is formed in deposits of Bognor Sand overlying the London Clay Formation. Typically, and in our experience, the London Clays do not exhibit any abnormal concentrations of naturally occurring chemical contaminants.

8.5.6 Source assessment – Fieldwork observations

8.5.6.1 A significant thickness of Made Ground was encountered across the site, containing fragments of anthropogenic material including brick, timber, concrete, glass and ash, suggesting the potential presence of a source of contamination. In addition, hydrocarbon odours were observed within Made Ground soils in a number of locations.

8.5.6.2 We obtained samples of the potentially chemically impacted soils for subsequent laboratory testing.

8.5.6.3 A hydrocarbon odour was noted within groundwater recovered from borehole DTS04.

8.5.7 Source assessment – summary

8.5.7.1 Based on the paragraphs above, we have identified the following potential sources of contamination:

Table summarising results of source assessment				
Source	Origin of information	Possible contaminant	Probability of risk occurring	Likely extent of contamination
On site				
Former household chemical factory	Site history	Metals/PAH/TPH/BTEX Asbestos/	Likely	Potentially site wide
Vehicle service and repair	Site history	TPH/BTEX	Likely	Potentially site wide
TPH contamination identified by previous investigation	Desk study	TPH/BTEX	Likely	Local to south-eastern site area
Made Ground	Fieldwork observations	Metals/PAH/asbestos	Likely	Site-wide
TPH in soils	Fieldwork observations	TPH/BTEX	Likely	Local to DTS01b
TPH in groundwater	Fieldwork observations	TPH/BTEX	Likely	DTS04
Adjacent sites				
Paint manufacturing plant	Site reconnaissance		Low likelihood	Local to eastern site boundary
Table reference 8.5.7				

8.6 Initial Conceptual Model

8.6.1 Based on our assessment of potential contaminative sources, identified receptors and viable pathways to receptors described in preceding paragraphs, we have produced an initial conceptual model in the form of a table which is presented in Appendix I.

8.6.2 Based on the conceptual model there are risks which exceed the low category which in our opinion are unacceptable, and require either remedial action or further investigation by laboratory testing of soil and groundwater samples to refine the risk assessment.

8.7 Laboratory testing

8.7.1 Testing regime

8.7.1.1 In order to carry out a quantitative assessment, we have scheduled testing to measure the concentration of commonly occurring inorganic and organic contaminants, total petroleum hydrocarbons and the presence/absence of asbestos

8.7.1.2 The following table summarises the chemical testing scheduled as well as a rationale for the testing:

Table summarising scheduled testing					
Exploratory point	Depth (m)	Strata/medium	Targeted sampling?	Scheduled testing	Rationale
BH01	0.5	Made Ground	N	Suite 1/ asbestos	General site coverage
	2.2	Groundwater	N	Suite 3/ Suite 9/TPH	
BH03	0.5	Made Ground	N	Suite 1/ asbestos	General site coverage
DTS01a	0.1	Made Ground	N	Suite 1/ asbestos	General site coverage
DTS01b	3.1	Made Ground	Y	Suite 7	Evidence for TPH contamination
	4.1	Made Ground	Y	Suite 7	
DTS02	0.4	Made Ground	N	Suite 1/ asbestos	General site coverage
DTS04	0.4	Made Ground	N	Suite 1/ asbestos	General site coverage
DTS04	1.35	Groundwater	Y	Suite 3/ Suite 9/TPH	Evidence for TPH contamination
DTS08	1.8	Bognor Sand Member	Y	Suite 7	Evidence for TPH contamination
DTS05	0.6-0.8	Made Ground	N	Suite 1/ asbestos	General site coverage
DTS06	0.2	Made Ground	N	Suite 1/ asbestos	General site coverage
	1.55	Made Ground	Y	Suite 7	Evidence for TPH contamination

Table 8.7.1.2

Table 8.7.1.2

Refer to Appendix A for testing suite descriptions

8.7.1.3 Additional testing (quantity and types) would allow a more accurate risk assessment to be made. The results of laboratory determination of concentration of chemical contaminants are presented in Appendix G.

8.7.2 Criteria for assessment of test data – Human receptors

8.7.2.1 Assessment of laboratory test data has been carried out with reference to current nationally recognised documents listed in the final page of Appendix A. Due to changes in guidance on contaminated land, items 6-8 and item 10 in the document listing above have been withdrawn. In the absence of alternative guidance however we have used these documents. Where new guidance is available, this has been followed in preference to superseded guidance.

8.7.2.2 The Land Quality Management (LQM) and the Chartered Institute of Environmental Health (CIEH) have derived Suitable for Use Levels (S4ULs) which are presented in *'The LQM/CIEH S4ULs for Human Health Risk Assessment'* (2015). S4ULs have been used as a screening tool to assess the risks posed to the health of humans from exposure to soil contamination in relation to appropriate land uses. Where published S4ULs are not available, we have adopted C4SLs (Category 4 Screening Levels) produced by DEFRA or SGVs (Soil Guideline Values) as appropriate. In the absence of any of these criteria we have adopted Soil Screening Values (SSV) derived by Soiltechnics and by Atkins (SSV^{ATK}). The CLEA model used to derive SSVs has been used with toxicology data presented by the EA, LQM/CIEH and Atkins (in that order of preference). SSVs produced by Atkins are presented on their ATRISK^{SOIL} website.

8.7.2.3 S4ULs, C4SLs, SGVs, SSVs and SSV^{ATK}s represent 'intervention values'; indications to an assessor that soil concentrations above these levels might present an unacceptable risk to the health of site users. These guideline values have been produced using conceptual exposure models, which use assumptions and are applied to differing end uses of land. If the values are exceeded, it does not necessarily imply there is an actual risk to health and site-specific circumstances should be taken into account. Conversely, where a critical pathway or chemical form of the contaminant has not been evaluated, a risk may be present even if the adopted guideline value has not been exceeded.

8.7.2.4 For evaluation of test data in relation to polycyclic aromatic hydrocarbon (PAH), phenols and total petroleum hydrocarbon (TPH) contamination, we have compared measured concentrations with corresponding S4ULs. The S4UL fractions are dependent on the Soil Organic Matter (SOM) content of the soils. We have adopted the relevant guideline values based on SOM testing.

- 8.7.2.5 We have followed procedures outlined by the CIEH to compare measured concentrations of metals and PAH contaminants against guideline values. TPH contamination results are compared directly with the relevant guideline values. The guidance presents an approach to data analysis and includes the examination of data for potential outliers, assessment of the normality of the test data and the calculation of a 95% Upper Confidence Limit (UCL). The UCL provides an estimate of the population mean, based on test data, with a 95% confidence that the actual mean does not exceed this value. The UCL is compared to the guideline value for the site.
- 8.7.2.6 We have adopted a commercial/industrial land use for proposed end users of the site.
- 8.7.3 Criteria for assessment of test data – Construction operatives**
- 8.7.3.1 In the absence of guidelines we have adopted industrial guideline values for assessment of construction operatives.
- 8.7.4 Criteria for assessment of test data – Vegetation**
- 8.7.4.1 Guidance published by Forest Research in "*BPG Note 5 - Best Practice Guidance for Land Regeneration*" suggests that a residential without plant uptake or industrial/commercial CLEA model should be adopted for this receptor although specific guideline values are provided for copper and zinc at 130mg/kg and 300mg/kg respectively. As a practice we have adopted the industrial / commercial CLEA model for assessment of test data for vegetation.
- 8.7.4.2 It is difficult to quantify the phytotoxicity of a contaminant as large variations exist between plant tolerances, soil effects and synergistic/antagonistic reactions between chemicals. Due to the complexities of the effects of soil contamination on different plant species, we recommend that the test results presented in this report are passed to a landscape architect for the selection of suitable planting.
- 8.7.5 Criteria for assessment of test data – Controlled waters**
- 8.7.5.1 For interpretation of test data in relation to water receptors we have directly compared measured values with the Environmental Quality Standards (EQS) and UK Drinking Water Standards (UKDWS). In the absence of EQS or UKDWS we have adopted World Health Organisation Drinking Water Guidelines (WHODWG)
- 8.7.5.2 EQS values are published by the Environment Agency in their publication, "*Environment Agency technical advice to third parties on Pollution of Controlled Waters for Part 11A of the Environmental Protection Act 1990*". EQS values for most inorganic contaminants in freshwater are dictated by the hardness of the receiving watercourse. The hardness of water is a measure of the concentration of calcium carbonate in the water. Although we have not sampled water from nearby watercourses, we have consulted BGS water hardness mapping, which identifies the area as containing very hard water (over 300mg/l).

8.7.5.3 Using this information for List II substances (DOE Circular 7/89) we have compared the measured values with the EQS values relative to the hardness of the receiving watercourse assuming a worst case scenario of the watercourse supporting 'sensitive' aquatic life.

8.7.5.4 UKDWS are presented in the Water Supply (Water Quality) Regulations.

8.7.5.5 Following our receptor assessment (outlined above), we have adopted EQS values in preference to alternative guidelines where possible, as no potable water supply boreholes are in the area and the site is not within a source protection zone.

8.7.6 Evaluation of test data – Human receptors

8.7.6.1 Tables summarising and analysing test data are presented in Appendix H. The following table summarises the outcome of the analyses.

Table summarising assessment of test data for human receptors

Analysis tables	Receptor group	Critical receptor	CLEA model	Inorganic contaminants	Organic contaminants
1, 2 and 4	Future site users and construction operatives	Adult	Industrial / commercial	No exceedances	No exceedances

Table 8.7.6.1

8.7.6.2 Asbestos was not identified in any of the sample submitted for screening.

8.7.6.3 Based on the above, laboratory testing has not identified any measured concentrations of contaminants which exceed current guideline values for human receptors. Based on the above evaluation, the concentrations of contaminants measured on soil samples taken from the site are considered unlikely to exhibit significant contamination from a perspective of human receptors.

8.7.7 Evaluation of test data – Vegetation

8.7.7.1 Comparison of test data with guideline values is presented on Tables 2 and 3 in Appendix H. None of the measured concentrations exceed the adopted guideline values. On this basis, we are of the opinion that measured concentrations are unlikely to exhibit significant contamination with respect to vegetation.

8.7.7.2 It is difficult to quantify the phytotoxicity of a contaminant as large variations exist between plant tolerances, soil effects and synergistic/antagonistic reactions between chemicals. Due to the complexities of the effects of soil contamination on different plant species, we recommend that the test results presented in this report are passed to a landscape architect for the selection of suitable planting.

8.7.8 Evaluation of test data – controlled waters

8.7.8.1 Inorganic contaminants

8.7.8.1.1 With reference to table 4 in Appendix H, dissolved concentrations of boron, cadmium, mercury and sulphate in the sample of groundwater from DTS04 exceed the adopted guideline values.

8.7.8.2 Organic contaminants (polycyclic aromatic hydrocarbons)

8.7.8.2.1 For the analysis of PAH contamination, the sum of the following contaminants has been compared to a UKDWS.

- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(ghi)perylene
- Indeno(1,2,3-cd)pyrene

8.7.8.2.2 The summed concentration of the PAH 'suite' do not exceed the UKDWS. In addition the dissolved concentrations of benzo(a)pyrene and naphthalene do not exceed their respective guideline values.

8.7.8.3 Organic contaminants (total petroleum hydrocarbons)

8.7.8.3.1 Petroleum hydrocarbons (TPH) were measured at a concentration of 8900µg/l in the sample of groundwater from DTS04, exceeding the UKDWS guideline of 10µg/l.

8.7.8.4 Summary

8.7.8.4.1 Based on the above evaluation, concentrations of boron, cadmium, mercury, sulphate and TPH in groundwater from borehole DTS04 pose a risk of harm to controlled water receptors. This is discussed further in Section 8.8 below.

8.8 Updated conceptual model

8.8.1 Having now completed analysis of laboratory testing, we can now update our conceptual model which is presented in Appendix H.

8.8.2 Human receptors

8.8.2.1 Concentrations of contaminants in soils at the site pose a low risk of harm to the health of site users and construction operatives. Remedial measures are therefore not required.

8.8.3 Controlled waters

8.8.3.1 Elevated concentrations of metals and petroleum hydrocarbons have been detected in a groundwater sample from the centre of the site (DTS04). At this stage, the source of the contamination is not known although, based on the likely groundwater flow direction beneath the site (southerly towards the Riders Lane Stream), the source would be expected to be to the north of DTS04. Groundwater appears to be confined within the Made Ground.

8.8.3.2 Further investigations are required in order to assess the nature and likely origin of the groundwater contamination. At this stage, we recommend the following actions are taken:

- An additional round of groundwater monitoring and analysis including sampling from Riders Lane Stream.
- Additional borehole investigations to determine the source of contamination and to install additional groundwater monitoring standpipes.
- Depending on the findings of further investigations, consultation with the Local Authority and Environment Agency. Early engagement may reduce the potential for delays later in the development process.

8.8.3.3 It is difficult to predict what the ultimate scope of additional investigations and/or remediation would be. Options may range from DQRA only to a medium to long-term monitoring programme up to a full-scale pump and treat remediation scheme.

8.9 Remedial action

8.9.1 Remedial action is not required in order to reduce risks to the health of site users.

8.9.2 Subject to the outcome of additional investigations, remedial measures may be required in order to reduce risks to controlled waters.

8.10 Risk assessment summary and recommendations

8.10.1 Based on our assessments described above, we can provide the following summary and recommendations for each identified receptor.

8.10.1 Based on our assessments described above, we can provide the following summary and recommendations for each identified receptor.

8.10.2 Future site users

8.10.2.1 As no source of significant chemical contamination has been identified on site, we are of the opinion that the site represents a low risk of causing harm to the health of users of the site.

8.10.3 Construction operatives and other site investigators

8.10.3.1 We recommend that risks to construction operatives and other site investigators during the construction phase are minimised by taking adequate precautions on site, potentially including:

- Supervision by an asbestos specialist and wearing appropriate PPE
- Wearing protective clothing, particularly gloves, to minimise ingestion from soil-contaminated hands
- Avoiding dust by dampening the soils during the works

8.10.3.2 Guidance on safe working practices can be obtained from the following documents:

- The Health and Safety Executive Publication *"Protection of Workers and the General Public during the Development of Contaminated Land"* (HMSO)
- *"A Guide to Safer Working on Contaminated Sites"* (CIRIA Report 132)

8.10.3.3 In addition, reference should be made to the Health and Safety Executive. In all cases work shall be undertaken following the requirements of the Health and Safety at Work Act 1974 and regulations made under the Act, including the COSHH regulations.

8.10.4 Controlled waters

8.10.4.1 Further investigations are required to determine the nature, extent and source of groundwater contamination.

8.10.5 Vegetation

8.10.5.1 As no source of significant chemical contamination has been identified on site, we are of the opinion that the site represents a low risk of causing harm to vegetation.

8.11 Statement with respect to National Planning Policy Framework

8.11.1 Providing the recommendations described above are satisfactorily completed, we are of the opinion the proposed development will be safe and suitable for use for the purpose for which it is intended, thus meeting the requirements of the National Planning Policy Framework section 121, and compliant with the Building Regulations Part C, *'Site preparation and resistance to contaminants and moisture'*

8.12 On Site Monitoring

8.12.1 We have attempted to identify the potential for chemical contamination on the site, however, areas, which have not been investigated at this stage, may exhibit higher levels of contamination. If such areas are exposed at any time during construction we will be pleased to re-attend site to assess what action is required to allow the development of safely proceed.

9 Gaseous contamination

9.1	Legislative framework
9.2	General
9.3	Assessment of source of gases
9.4	Gas migration
9.5	Conceptual model
9.6	Development categorisation
9.7	Interim monitoring observations
9.8	Interim classification of site characteristic gas situation
9.9	Interim assessment of gas protective measures

9.1 Legislative framework

- 9.1.1 There is currently a complex mix of documentation relating to legislative and regulatory procedures on the issue of contamination and it is not considered a purpose of this report to discuss the detail of these regulations. Essentially, Government Policy is based on *'suitable for use approach'*, which is relevant to both the current and proposed future use of land. For current use Part IIA of the Environmental Protection Act 1990 provides the regulatory regime (see Section 8.1 above). The presence of harmful soil gases could provide a 'source' in a 'pollutant linkage' allowing the regulator (Local Authority) to determine if there is a significant possibility of harm being caused to humans, buildings or the environment. Under such circumstances the regulator would determine the land as 'contaminated' under the provision of the Act requiring the remediation process to be implemented with the Environment Agency responsible for enforcement.
- 9.1.2 The Town and Country Planning (General Development Procedure) Order 1995, requires the planning authority to consult with the Environment Agency before granting planning permission for development on land within 250 metres of land which is being used for deposit of waste, (or has been at any time in the last 30 years) or has been notified to the planning authority for the purposes of that provision.
- 9.1.3 Building control bodies enforce compliance with the Building Regulations. Practical guidance is provided in Approved documents, one of which is Part C, *'Site preparation and resistance to contaminants and moisture'* which seeks to protect the health, safety and welfare of people in and around buildings and includes requirements for protection against harm from soil gas.

9.2 General

- 9.2.1 The following assessment relates to the potential for, and the effects of, gases generated by biodegradable matter. The potential for the development to be affected by radon gas is considered in Section 3 above. The principal ground gases are carbon dioxide (CO₂) and methane (CH₄). The following table provides a summary of the effects of these gases when mixed with air.

Significant gas concentrations in air		
Gas	Concentration by volume	Consequence
Methane	0.25%	Ventilation required in confined spaces
	5 - 15%	Potentially explosive when mixed with air
	30%	Asphyxiation
	75%	Death after 10 minutes
Carbon Dioxide	0.5%	8 hour long term exposure limit (LTCL) (HSE workplace limit)
	1.5%	15 min short term exposure limit (STCL) (HSE workplace limit)
	>3%	Breathing difficulties
	6 – 11%	Visual distortion, headaches, loss of consciousness, possible death
	>22%	Death likely to occur

Table 9.2.1

9.2.2 Following the current Building Regulations Approved Document C1, Section 2 'Resistance to Contaminants' (2004 incorporating 2010 and 2013 amendments) a risk assessment approach is required in relation to gaseous contamination based on the source-pathway-receptor conceptual model procedure. We have adopted procedures described in the following reference documents for investigation and assessments of risk of the development being affected by landfill type gases (permanent gases) and if appropriate the identification of mitigation measures.

- BS10175:2011 'Investigation of potentially contaminated sites- Code of Practice'
- BS8576:2013 'Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'
- BS8485:2015 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'
- CIRIA Report C665 'Assessing risks posed by hazardous ground gases to buildings' (2007)
- CL:AIRE Research Bulletin RB17 'A pragmatic approach to ground gas risk assessment' (November 2012)

Whilst we have followed the guidance and recommendations of BS8576, we have used BS8485:2015 to derive recommendations for protective works.

9.2.3 An assessment of the risk of the site being affected by ground gases is based on the following aspects:

- a) Source of the gas
- b) Investigation information
- c) Migration feasibility
- d) Sensitivity of the development and its location relative to the source

9.3 Assessment of source of gases

9.3.1 General sources

9.3.1.1 The following table summarises the common sources of ground gases and parameters affecting the generation of ground gases:

Source and control of gases	
Type	Parameters affecting the rate of gassing
Landfills	Portion of biodegradable material, rate reduces with time
Mineworkings	Flooding reduces rate of gassing
Dock silt	Portion of organic matter
Carbonate deposits	Ground / rainwater (acidic) reacts with some carbonates to produce carbon dioxide.
Made Ground	Thickness of Made Ground and proportion of degradable organic matter
Naturally deposited soils/rocks	Portion of organic matter

nditions, pH, temperature

Table 9.3.1

9.3.1.2 As the site is not within a dockland environment or an area affected by mineworkings, and near surface soils do not exhibit high carbonate content, then potential gas sources are limited to landfills and/or soils with a high proportion of organic matter.

9.3.2 Landfill and infilled ground sources

9.3.2.1 Waste Management Paper 27 (1991) produced by the Department of the Environment 'Control of Landfill Gases' contains the recommendation to avoid building within 50m of a landfill site actively producing large quantities of landfill type gases and to carry out site investigations within a zone 250m beyond the boundary of a landfill site.

9.3.2.2 No distinction is made between sites of differing ground conditions, but the paper does not advocate the site is safe beyond the 250m zone, dependant, of course, upon the type of landfill and potential for migration of landfill gases.

9.3.2.2 There are no recorded landfill sites artificial deposits or BGS Recorded Mineral Sites within 1000m of the subject site. In addition, we have reviewed old Ordnance Survey maps and there is no obvious evidence of any quarrying in the area which may have been restored with materials which could generate landfill gases. On the above basis there is no recorded evidence to suggest a source of landfill gases from such past activities.

9.3.3 Soil conditions

9.3.3.1 None of the soils observed in exploratory excavations, in our opinion, exhibit significant concentrations of organic matter which are likely to produce elevated quantities of carbon dioxide and / or methane gas.

9.3.3.2 Made Ground thicknesses are significant and in the range of 1.2 to 4.5m (where the full thickness was proven). Laboratory testing indicates that the Made Ground soils beneath the site contain between 0.48% and 3.3% of organic matter. Significant incidences of degradable materials were not noted, although it should be noted that soil observation were in small diameter boreholes only. Due to the thickness and heterogeneity of the Made Ground, this is considered to represent a source of ground gas with the potential to affect the site.

9.3.4 Source assessment summary

9.3.4.1 The following table summarises the possibility of a source of landfill type gases.

Source assessment summary		
Potential source origin	Viability of source	Evidence
Landfills	Unlikely	Desk study information
Mineworkings	Unlikely	Desk Study information Geological conditions not amenable
Dock silt	Unlikely	Site remote from dockland environment
Carbonate deposits	Unlikely	Recorded and observed soil conditions do not indicate high concentrations of carbonates
Made Ground	Likely	Made Ground >4m thickness
Naturally deposited soils/rocks	Unlikely	Soils exposed in exploratory excavations do not exhibit high concentrations of organic matter
Table 9.3.4		

9.3.4.2 Based on the above it there is a possibility of a source of potential landfill gases which may affect the subject site. On this basis, it is considered necessary to consider possible pathways for migration of ground gases from this potential source to the site.

9.4 Gas migration

9.4.1 Exploratory excavations encountered predominantly coarse-grained Made Ground to depths of 4.5m. In our opinion, these deposits are relatively permeable and would provide little resistance to both lateral and vertical migration of landfill type gases. It is therefore considered possible that the potential on-site source of landfill type gases (identified in Section 9.3) could feasibly migrate to the ground surface of the site.

9.5 Conceptual model

- 9.5.1 Based on the above, there is a potential source of landfill type gases, and a feasible migration pathway. Our conceptual model is tabled below. On this evidence we are of the opinion that the site is at risk of being affected by ground gases (carbon dioxide / methane) sufficient to potentially cause harm to human end users of the site, construction operatives or indeed buildings. On this basis, we have installed monitoring standpipes in boreholes and implemented a monitoring regime, generally following procedures described in BS8576:2013 to quantify the risk and, if appropriate, identify mitigation measures.

Conceptual model		
Potential source origin	Potential pathway	Receptors at risk
Made Ground	Via coarse-grained Made Ground	End users Construction operatives Buildings

Table 9.5.1

9.6 Development categorisation

- 9.6.1 With reference to BS8485:2015 (table 3), the proposed building type would be classified as 'Type C- Commercial/public'.

9.7 Initial Monitoring observations

- 9.7.1 Four standpipes have been installed at the site in accordance with BS9576:2013, Section 9 (refer Drawing 07). Following BS8576:2013 (Figure 6) and CIRIA Report C665 (Tables 5.5a and 5.5b) we have provisionally assessed the site as very low risk of generation potential of source ideally requiring 4 monitoring visits over a one month period. This initial assessment will be reviewed pending the results of further monitoring observations.
- 9.7.2 We have returned to site for two of the four proposed monitoring visits to obtain measurements of landfill type gases at atmospheric conditions in the range of 1012 to 1033mb and temperatures in the range of 0°C to 11°C. Essentially we detected concentrations of methane in the range of <0.1 to 0.2%, with concentrations of carbon dioxide measured in the range of 0.1 to 11.4%. If flows were detected during our monitoring visits then these are recorded, but where no flow is detected then we have assumed flow at the detection limit of the monitoring equipment at 0.1l/s.
- 9.7.3 Gas monitoring results are summarised in Appendix J.

9.8 Interim classification of site characteristic gas situation

- 9.8.1 Using test data obtained to date, and with reference to Table 2 of BS8485:2015, the site would be classified as **characteristic gas situation 2**. This is an interim classification based on observations to date and can only be confirmed following additional monitoring visits. It should be noted however, that there is a possibility of higher flow measurements being recorded during low atmospheric conditions, which may increase the classification of the site requiring more onerous gas protective measures.

9.9 Interim assessment of gas protective measures

- 9.9.1 Based on monitoring observations to date, development categorisation (section 9.6 above), and the interim site characteristic gas situation (section 9.8 above) and with reference to Table 4 of BS8485:2015, the development requires gas protective measures which would achieve a '*gas protection score*' of 2.5. Lists of protective measures which each produce a score value are produced in Tables 5, 6 and 7 of BS8485:2015. Clearly this is an interim assessment based on observations to date and can only be confirmed following additional monitoring visits. It should be noted however, that there is a significant possibility of higher flow measurements being recorded during low atmospheric conditions which may increase the classification of the site requiring more onerous gas protective measures.

10 Effects of ground conditions on building materials

10.1	Hazard
10.2	Assessment
10.3	Desk study information
10.4	Assessment of Design Sulphate Class
10.5	Assessment of groundwater mobility
10.6	Assessment of aggressive chemical environment for concrete (ACEC)
10.7	Concrete – magnesium attack
10.8	Concrete – ammonium attack
10.9	Plastic pipes

10.1 Hazard

10.1.1 Sulphate attack on concrete is characterised by expansion, leading to loss of strength, cracking, spalling and eventual disintegration. There are three principal forms of sulphate attack, as follows:-

- Formation of gypsum through reaction of calcium hydroxide and sulphate ions.
- Ettringite formation through reaction of tricalcium aluminate and sulphite ions.
- Thaumasite formation as a result of reactions between calcium silicate hydrates, carbonate ions (from aggregates) and sulphate ions.

10.2 Assessment

10.2.1 The hazard of sulphide attack is addressed by reference to procedures described in Building Research Establishment (BRE) Special Digest 1: 2005 '*Concrete in Aggressive Ground*' to establish a design sulphate class (DS) and the '*Aggressive Chemical Environment for Concrete*' (ACEC). These procedures have been followed during our investigation and are described in the following paragraphs.

10.3 Desk Study Information

10.3.1 The first step in the procedure is to consider specific elements of the desk study. These are tabulated below.

Summary of desk study information				
Element	Interrogation		Outcome	SD1: 2005 reference
Geology	Likelihood of soils containing pyrites	Made Ground	Possible	Box C6
		Bognor Sand Member	Possible	
		London Clay Formation	Likely	
Past industrial uses	Brownfield site?		Yes	C2.1.2

Table 10.3.1

10.3.2 A brownfield site is defined in SD1: 2005 as a site, or part of a site which has been subject to industrial development, storage of chemicals (including for agricultural use) or deposition of waste, and which may contain aggressive chemicals in residual surface materials, or in ground penetrated by leachates. Where the history of the site is not known, it should be treated as brownfield until there is evidence to classify it as natural.

10.3.3 Based on the above it is necessary to follow the procedures described in Section C5.1.4 (*'Brownfield locations that contain pyrite'*).

10.4 Assessment of Design Sulphate Class

10.4.1 The sulphate concentration in a 2:1 water/soil extract was measured in two samples of Made Ground, two samples of Bognor Sand Member and four samples of the London Clay Formation. The highest test result for the soil type has been adopted as the characteristic value.

10.4.2 Due to the potential for foundation arisings to be used as bulk fill, following the recommendations of SD1: 2005, we have scheduled additional testing on the same soil samples to include:-

- Determination of total sulphate content (% SO₄)
- Determination of total sulphate present (% S)

Using this test data we have calculated the total potential sulphate content (TPS, % SO₄) and the amount of oxidisable sulfides (OS % SO₄), again following the procedures described in SD1: 2005. As the amount of oxidisable sulfides exceeds 0.3% SO₄ in a significant number of samples of London Clay, pyrite is probably present in these deposits.

10.4.3 The characteristic total potential sulphate content has been based on the highest TPS value (rounded to 0.1% SO₄, refer to table 8.6.1). With reference to table C1 of SD1: 2005, the design sulphate class has been based on considering both the initial characteristic value, and characteristic total potential sulphate content, and adopting the more onerous of these two values.

10.5 Assessment of groundwater mobility

10.5.1 With reference to SD1: 2005, we are of the opinion that for Made Ground and Bognor Sand Member, ground conditions at the site suggest 'mobile groundwater' conditions. 'Static groundwater' conditions have been adopted for London Clay.