



**PHASE 2
GROUND INVESTIGATION REPORT**

for the site at

**LAND ADJ. TO STATION ROAD AND WELLINGTON ROAD, WOKINGHAM, BERKSHIRE
RG40 2AE**

on behalf of

WOKINGHAM HOUSING LIMITED

Report Reference: GWPR2800/GIR/November 2018		Status: FINAL
Issue:	Prepared By:	Verified By:
V1.01 November 2018		
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File Reference: Ground and Water/Project Files/ GWPR2800 Land adj. to Station Road and Wellington Road, Wokingham RG40 2AH		

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1.0 INTRODUCTION

1.1 General

Ground and Water Limited were instructed by Wokingham Housing Limited, on the 19th September 2018, to conduct a Ground Investigation on a potential redevelopment site on the land adj. to Station Road and Wellington Road, Wokingham, Berkshire RG40 2AE. The scope of the investigation was detailed within the Ground and Water Limited fee proposal, ref. GWQ4069, dated 14th August 2018.

1.2 Aims of the Investigation

The aim of the investigation was understood to be to supply the client and their designers with information regarding the ground conditions underlying the site to assist them in preparing an appropriate scheme for development.

The investigation was to be undertaken to provide parameters for the design of foundations by means of in-situ and laboratory geotechnical testing undertaken on soil samples recovered from trial holes.

Included within the fee proposal was an allowance to undertake chemical laboratory testing on soil samples recovered from the site to enable recommendations for the safe redevelopment of the site and the protection of site workers, end-users and the public from any potential contamination identified, as detailed in the Conceptual Site Model (CSM) within the Ground and Water Limited Desk Study Report (ref. GWPR2800/DS/November 2018) or the revised CSM within this report. This Ground Investigation Report must be read in conjunction with the Desk Study Report.

The techniques adopted for the investigation were chosen considering the requirements of the client, anticipated ground conditions, and bearing in mind the nature of the site, limitations to site access and other logistical limitations.

1.3 Conditions and Limitations

This report has been prepared based on the terms, conditions and limitations outlined within Appendix A.

2.0 SITE SETTING

2.1 Site Location

The site comprised a 2,000m² irregular shaped plot of land, orientated in north-west to south-east direction, located on the north-eastern side of Wellington Road. The site was located within Wokingham, a town within Berkshire, ~7miles south-east of Reading.

The national grid reference for the centre of the site was approximately TQ 30391 72607. A site location plan is given within Figure 1. A plan showing the site boundary can be seen in Figure 2.

2.2 Site Description

A Site Walkover was undertaken on the 10th October 2018. A description of the site, as noted during the Site Walkover, is tabulated below and overleaf. An aerial view of the site showing an approximate site boundary is given within Figure 3.

Site Description Sheet - Land adj. to Station Furniture, 46 Station Road, Wokingham RG40 2AE	
Use of site	At the time of the Site Walkover, October 2018, the site was primarily being used as a temporary car park for the surrounding shops. A brick retaining wall separated the north-western and south-eastern halves of site. The area to the north-west of site sitting ~1.00m lower than the remainder.
Site topography	The north-western portion of site sat ~1.00m lower than the remainder of site, separated with a brick retaining wall. An embankment was noted along the south-western boundary. The south-western boundary comprised an area of embanked land, 0.50 – 0.75m in height, associated with the construction of a new public pavement along Wellington Road.
Area topography	The area in which the site was located was generally flat and level.
Structures on-site	No structures were noted onsite.
Structures off-site & Use of surrounding ground.	The surrounding area to the north-east/east was primary commercial. Single-storey, brick-built furniture shop and car washing facility, and car park for these facilities, were located directly next to the north-eastern boundary. The area to the south-west was used for a railway line and Wokingham Station. The remainder of the site along Wellington Road and Park Road to the east/south-east primarily comprised residential housing.
Boundary features	North-western boundary: The boundary was open and located in the corner of Wellington Road and Station Road. North-eastern boundary: The party wall of the neighbouring furniture shop was noted to the north, with the remainder comprising Heras fencing between the site and the car wash/car park to the north-east. South-western boundary: ~1.00m high wooden railed fencing between the site and Wellington Road. An area of embanked land was noted to the south due to the construction of new public pavement. South-eastern boundary: Thick vegetation comprising overgrown shrubs and ~10m high trees. Park Road was noted directly behind the site to the south-east.
Site covering	The site was primarily covered with grassed soft landscaping. The north-western portion of the site comprised paved hardstanding with the centre of the site comprising concrete hardstanding used for a temporary car park.
Contamination sources on-site	- Embanked land along the south-western boundary. - Use of site as a car park.

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Site Description Sheet Cont'd - Land adj. to Station Furniture, 46 Station Road, Wokingham RG40 2AE	
Contamination sources off-site	• Car washing facility directly north-west. • An over ground railway directly across Wellington Road. • Electricity sub-station ~20m west. No evidence of asbestos was identified within the buildings along the north-eastern boundary.
Vegetation on-site	The site was primarily covered with soft grass landscaping. Thick vegetation and ~10m high trees was noted along the south-eastern boundary between the site and Park Road. 1No. ~10m high tree was also noted along the south-western boundary.
Vegetation off-site	A number of shrubs and bushes were noted along Wellington Road. Private residential gardens were also noted to the east of site along Park Road.
Services	None noted onsite.

2.3 Proposed Development

At the time of reporting, November 2018, the proposed development was understood to comprise a retail space in the north-western corner of site, with a number of self-contained residential flats and parking spaces to the south-east. Areas of communal soft landscaping will be created along the south-western boundary for the residential flats. It was understood that the existing car washing facility in the north-east of site was to remain. A plan view of the proposed development can be seen in Figure 4.

2.4 Geology

The geology map of the British Geological Survey of Great Britain of the Wokingham area (Sheet No. 268, Reading) revealed that the site was anticipated to be located on the bedrock deposits of the Bagshot Formation. Areas of Made Ground were noted ~190m north-west, ~190m south-east and ~220m south-west.

Made Ground

Made Ground is shown in areas where material was deposited by man upon the natural ground surface. There are two main categories:

- Natural materials produced either as spoil from mineral extractions, or dug for the construction of various embankments and raised areas, including bunds for flood defenses.
- Waste in landfill sites; recycling of waste construction materials is leading to their increased usage in urban and industrial landscaping.

Bagshot Formation

Bagshot Beds comprise mainly fine to medium grained yellow, pink and brown sand with ferruginous concretions. Beds of grey clay "pipe clay" occur frequently as do beds of black flint gravel.

2.5 Hydrogeology and Hydrology

A study of the aquifer maps on the DEFRA website and within the Groundsure Datasheets, presented in Appendix D of this report, revealed the site to be located on **Secondary A Aquifer** relating to the bedrock deposits of the Bagshot Formation. No designation was given for superficial deposits due to their likely absence.

Superficial (Drift) deposits are permeable unconsolidated (loose) deposits, for example, sands and gravels. The bedrock is described as solid permeable formations e.g. sandstone, chalk and limestone.

Secondary aquifers include a wide range of drift deposits with an equally wide range of water permeability and storage capacities.

Secondary (A) Aquifers consist of deposits with 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. These are generally aquifers formerly classified as Minor Aquifers.

Examination of the DEFRA records showed that the site did not fall within a Groundwater Source Protection Zone as classified in the Policy and Practice for the Protection of Groundwater.

The nearest surface water feature was an unnamed pond ~100m east. The Emm Brook was noted ~520m south-west of site, flowing in a north-westerly direction.

From analysis of hydrogeological and topographical maps groundwater was anticipated to be encountered at moderate depth (4 - 7m below existing ground level (bgl)) and it was considered that the groundwater was flowing in a north-westerly direction in accordance with the local topography.

Examination of the Environment Agency records showed that the site fell within a **Flood Zone 1** (an area with a low probability of river or sea flooding).

2.6 Radon

BRE 211 (2007) Map 4 of Hampshire, Berkshire and South Oxfordshire revealed the site **was not** located within an area where mandatory protection measures against the ingress of Radon were required. The site **was not** located within an area where a risk assessment was required.

FIELDWORK

3.0 Scope of Works

Site works were undertaken on 10th October 2018 and comprised the drilling of 4No. Windowless Sampler Borehole (WS1 – WS4) to 0.80 – 3.45m bgl and 1No. hand-dug pit to 1.00m bgl (TP1). Standard Penetration Tests were undertaken at 1.00m intervals in WS1, WS2 and WS4. Super Heavy Dynamic Probes (DP1 – DP4) were undertaken through the base of WS1 – WS4 to depths of between 5.00 – 10.00m bgl. 2No. CBR by DCP (DP1 – DCP2) were also undertaken.

Further attempts at Windowless Sampler Boreholes were undertaken in the vicinity of WS3 (TP2 – TP3), but due to a concrete obstruction, could not be undertaken past 0.50 – 0.60m bgl.

A falling head test was undertaken in WS2 and WS4 at a depth of 2.10 – 2.20m bgl.

1No. combined ground-gas and groundwater monitoring well was installed to a depth of 1.70m bgl. The construction details can be seen tabulated below:

Groundwater Monitoring Well Construction				
Trial Hole	Depth of Installation (m bbl/brgl)	Thickness of slotted piping with gravel filter pack (m)	Depth of plain piping with bentonite seal (m bgl)	Piping external diameter (mm)
WS1	1.70	1.20	0.50	50

It should be noted that WS1 was undertaken ~1.00m lower than all other trial holes due to level changes from a retaining wall.

The approximate location of the trial holes can be seen within Figure 5.

Prior to commencing the ground investigation, a walkover survey was carried out to identify the presence of underground services and drainage. Where underground services/drainage were suspected and/or positively identified, the exploratory position was relocated away from these areas.

Upon completion of the drilling works, the trial holes were backfilled and made good, in relation to the surrounding area.

3.1 Sampling Procedures

Small disturbed samples were recovered from the trial holes at the depths shown on the trial hole records. Soil samples were generally retrieved from each change of strata and/or at specific areas of concern. Samples were also taken at approximately 0.5m intervals during broad homogenous soil horizons.

A selection of samples were despatched for geotechnical testing purposes. In addition, three soil samples were also sent off for analysis for a broad range of contaminants in accordance with the Conceptual Site Model (CSM) developed within the Ground and Water Desk Study Report (ref. GWPR2800/DS/November 2018) and DEFRA/CLEA methodologies.

4.0 ENCOUNTERED GROUND CONDITIONS

4.1 Soil Conditions

The trial holes were logged by Alice Tettmar of Ground and Water Limited generally in accordance with BS EN 14688 'Geotechnical Investigation and Testing – Identification and Classification of Soil'.

The ground conditions encountered within the trial holes excavated on the site did not generally conform to that anticipated from examination of the geology map. A capping of Made Ground was noted to overlie 6th River Terrace Deposits and the Bagshot Formation.

The ground conditions encountered during the investigation are described in this section. The trial hole logs can be seen in Appendix B and the trial hole location plan can be viewed in Figure 5.

For the purposes of discussion, the succession of conditions encountered in the trial holes in descending order can be broadly summarised as follows:

Made Ground
6th River Terrace Deposits
Bagshot Formation

Made Ground

Made Ground was encountered from ground level in WS1 – WS3 and TP1 – TP3 and below a 0.15m thick brick paving in WS3. The soils were noted for the full depth of TP1 – TP3 and WS3 (0.50 – 1.00m bgl) and to 0.30 – 0.75m bgl in WS1, WS2 and WS4. The soils generally comprised a dark brown/grey silty gravelly sandy clay to a clayey gravelly sand. The sand was fine to coarse grained and the gravel was occasional, fine to coarse, sub-rounded to angular flints, brick, concrete, ceramic and tarmac fragments.

6th River Terrace Deposits

Soils described as the 6th River Terrace Deposits were encountered underlying the Made Ground from 0.30 – 0.70m bgl in WS1, WS2 and WS4 to depths of between 1.60 – 2.30m bgl. The soils generally comprised orange brown/brown/blue/grey gravelly clays/clays and clayey sands over a clayey gravelly sand. The sand was fine to coarse grained and the gravel was occasional, fine to medium, sub-angular to angular flints.

Bands of cohesive material was encountered in WS1 between 0.30 – 0.70m bgl, WS2 between 1.20 – 1.80m bgl and WS4 between 1.10 – 1.60m bgl. The soils generally comprised an orange brown/brown/blue/grey mottled gravelly sandy clay. The sand was fine to coarse grained and the gravel was occasional, fine to medium, sub-angular to angular flints.

Bagshot Formation

The Bagshot Formation was noted underlying the 6th River Terrace Deposits from 1.60 – 2.30m bgl for the remainder of WS1, WS2 and WS4, depths of between 2.45 – 3.45m bgl. The soils generally comprised an interbedded orange brown/grey/blue mottled silty clayey sand to a silty sandy clay. The sand was fine to coarse grained.

For details of the composition of the Made Ground, 6th River Terrace Deposits and Bagshot Formation at particular points, reference must be made to the trial hole logs within Appendix B.

4.2 Roots Encountered

Roots were noted to 0.70 – 1.50m bgl in TP1 and WS1 – WS4. Traces of decayed roots were noted to 2.50m bgl in WS4.

Roots may be found to greater depths at other locations on the site, particularly close to trees and/or trees that have been removed both within the site and its close environs.

4.3 Groundwater Conditions

Groundwater encountered during the intrusive investigation can be summarised below.

Water Strikes Encountered		
Borehole	Depth of Strike/Ingress (m bgl)	Standing Depth (m bgl)/Time
WS1	1.00 - 2.00	1.60m after 20 minutes
WS2	2.00 - 3.00	2.10m after 20 minutes
WS4		

Changes in groundwater level occur for a number of reasons including seasonal effects and variations in drainage. Exact groundwater levels may only be determined through long term measurements from monitoring wells installed on-site.

The site investigation was conducted in October 2018, when groundwater levels should be rising to their annual maximum (highest elevation). The long-term groundwater elevation might increase at some time in the future due to seasonal fluctuation in weather conditions. Isolated pockets of groundwater may be perched within any Made Ground/Topsoil found at other locations around the site.

4.4 Obstructions

Due to a suspected concrete obstruction WS3, TP2 and TP3 could not be continued past 0.50 – 1.00m bgl. The presence of water in WS1, WS2 and WS4 caused the trial holes to collapse, preventing further drilling past 2.45 – 3.45m bgl.

4 INSITU AND LABORATORY GEOTECHNICAL TESTING

5.1 In-Situ Geotechnical Testing

5.1.1 Standard Penetration Tests (SPTs)

Standard Penetration Tests (SPTs) were undertaken at 1.00m intervals in WS1, WS2 and WS4. The results of the SPT's have not been amended to consider hammer efficiency, rod lengths and overburden pressure in accordance with Eurocode 7. The test results are presented on the borehole logs within Appendix B.

Windowless Sample Boreholes provide samples of the ground for assessment but they do not give any engineering data. The standard penetration test (SPT) is an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil. The test uses a thick-walled sample tube, with an outside diameter of 50 mm and an inside diameter of 35 mm, and a length of around 650mm. This is driven into the ground at the bottom of a borehole by blows from a slide hammer with a weight of 63.5 kg falling through a distance of 760 mm. The sample tube is driven 150 mm into the ground and then the number of blows needed for the tube to penetrate each 75 mm up to a depth of 450 mm is recorded. The sum of the number of blows is termed the "standard penetration resistance" or the "N-value".

The cohesive soils of the 6th River Terrace Deposits and Bagshot Formation were classified based on the table below.

Undrained Shear Strength from Field Inspection/SPT Results Cohesive Soils (EN ISO 14688-2:2004 & Stroud (1974))		
Classification	Undrained Shear Strength (kPa)	Field Indications
Extremely High	>300	-
Very High	150 – 300	Brittle or very tough
High	75 – 150	Cannot be moulded in the fingers
Medium	40 – 75	Can be moulded in the fingers by strong pressure
Low	20 – 40	Easily moulded in the fingers
Very Low	10 – 20	Exudes between fingers when squeezed in the fist
Extremely Low	<10	-

The granular soils of the 6th River Terrace Deposits and Bagshot Formation were classified based on the table below.

Correlation between normalised SPT blow counts (N_1) ₆₀ or equivalent 'SPT's derived from SHDP results and granular classification.	
Classification	Equivalent SPT Blow Counts (N_1)
Extremely Dense	>58
Very Dense	42 – 58
Dense	25 – 42
Medium	8 – 25
Loose	3 – 8
Very Loose	0 – 3

An interpretation of the in-situ geotechnical testing results is given in the table overleaf.

Interpretation of In-situ Geotechnical Testing Results – Based on SPT Results					
Strata	SPT “N” Blow Counts	Equivalent Undrained Shear Strength (kPa) Cohesive Soils	Soil Type		Trial Hole/s
			Cohesive	Granular	
6 th River Terrace Deposits (cohesive)	18 8	90 40	High Medium	-	WS2 (1.20 – 1.80m bgl) WS4 (1.10 – 1.60m bgl)
6 th River Terrace Deposits (granular)	28	-	-	Dense	WS1 (0.70 – 1.80m bgl)
Bagshot Formation (cohesive)	5 10	25 50	Low Medium	-	WS1 (1.80 – 2.45m bgl) WS4 (2.50 – 3.45 bgl)
Bagshot Formation (granular)	21 7	-	-	Medium Loose	WS2 (2.30 – 3.00m bgl) WS4 (1.60 – 2.50m bgl)

Interpretation of In-situ Geotechnical Testing Results – Based on SHDP results					
Strata	Equivalent SPT “N” blow counts	Equivalent Undrained Shear Strength (kPa) Cohesive Soils	Soil Type		Trial Hole/s
			Cohesive	Granular	
ASSUMED 6 th River Terrace Deposits (cohesive)	13 – 14	65 – 70	Medium	-	DP1 (0.30 – 0.70m bgl)
ASSUMED 6 th River Terrace Deposits (granular)	10 – 29 4 – 17	-	-	Medium – Dense Loose – Medium	DP1 (0.70 – 1.80m bgl) DP3 (1.40 – 2.20m bgl)
ASSUMED Bagshot Formation (cohesive)	2 – 3 1 – 4	10 – 15	Very Low	-	DP1 (2.30 – 2.90m bgl) DP2 (3.10 – 5.00m bgl)
ASSUMED Bagshot Formation (granular)	17 – 63 5 2 – 9	-	-	Medium – Extremely Dense Loose Very Loose – Medium	DP3 (2.10 – 3.70m/4.10 – 10.00m bgl) DP3 (1.80 – 2.10m/3.70 – 4.10m bgl) DP4 (3.60 – 5.00m bgl)

The SHDP undertaken on the cohesive soils of the 6th River Terrace Deposits and Bagshot Formation may underestimate the undrained shear strength.

It must be noted that field measurements of undrained shear strength are dependent on a number of variables including disturbance of sample, method of investigation and also the size of specimen or test zone etc.

5.1.2 In-Situ CBR by DCP Tests

DCP testing was carried out at 2No. locations across the site to determine the equivalent CBR values of the soils underlying the site at shallow depth (0.92m bgl) in accordance with BS1377 Part 9:2016:4.3 and a summary of the results are tabulated below. The full results can be seen in Appendix C.

DCP Test Results Summary						
Test Location	Layer One		Layer Two		Layer Three	
	Thickness (mm)	CBR (%)	Thickness (mm)	CBR (%)	Thickness (mm)	CBR (%)
1	219	22	525	15	847	38
2	211	12	488	22	139	49

5.2 Laboratory Geotechnical Testing

A programme of geotechnical laboratory testing, scheduled by Ground and Water Limited and carried out by K4 Soils Laboratory and DETS Limited, was undertaken on samples recovered from the 6th River Terrace Deposits and the Bagshot Formation. The results of the tests are presented in Appendix D.

The test procedures used were generally in accordance with the methods described in BS1377:2016. Details of the specific tests used in each case are given below.

Standard Methodology for Laboratory Geotechnical Testing		
Test	Standard	Number of Tests
Atterberg Limit Tests	BS1377:2016:Part 2:Clauses 3.2, 4.3 & 5	3
Particle Size Distribution	BS1377:2016:Part 2:Clause 9	2
Water Soluble Sulphate & pH	BS1377:2016:Part 3:Clause 5	1
BRE Special Digest 1 (incl. Ph, Electrical Conductivity, Total Sulphate, W/S Sulphate, Total Chlorine, W/S Chlorine, Total Sulphur, Ammonium as NH ₄ , W/S Nitrate, W/S Magnesium)	BRE Special Digest 1 "Concrete in Aggressive Ground (BRE, 2005).	2

5.2.1 Atterberg Limit Tests

A précis of the Atterberg Limit Test results undertaken on one sample of 6th River Terrace Deposits and two samples of the Bagshot Formation can be seen tabulated below.

Atterberg Limit Tests Results Summary							
Stratum/Depth	Moisture Content (%)	Passing 425 µm sieve (%)	Modified PI (%)	Soil Class	Consistency Index (Ic)	Volume Change Potential	
						NHBC	BRE
6 th River Terrace Deposits	17	89	19.58	Cl	Very Stiff	Low	Low
Bagshot Formation	20 – 24	93 – 94	23.50 – 24.18	Cl	Firm – Stiff	Medium	Medium

NB: NP – Non-plastic
 BRE Volume Change Potential refers to BRE Digest 240 (based on Atterberg results)
 Soil Classification based on British Soil Classification System.
 Consistency Index (Ic) based on BS EN ISO 14688-2:2004.

5.2.2 Comparison of Soil's Moisture Content with Index Properties

5.2.2.1 Liquidity Index Analyses

The results of the Atterberg Limit test undertaken on one sample of 6th River Terrace Deposits and two samples of the Bagshot Formation was analysed to determine the Liquidity Index of the samples. This gives an indication as to whether the samples

recovered showed a moisture deficit and their degree of consolidation. The results are tabulated over page.

The test results are presented within Appendix D.

Liquidity Index Calculations Summary					
Stratum/Trial Hole/Depth	Moisture Content (%)	Plastic Limit (%)	Modified Plasticity Index (%)	Liquidity Index	Result
6th River Terrace Deposits WS4/1.20m bgl Yellowish brown, orange and occasional light grey slightly gravelly sandy silty CLAY with traces of rootlets (gravel is fm and sub-angular)	17	15	19.58	0.10	Heavily Overconsolidated
Bagshot Formation WS1/1.80m bgl Orange and occasional light grey slightly gravel sandy silty CLAY (gravel is fm and sub-angular)	24	14	24.18	0.41	Overconsolidated
Bagshot Formation WS4/2.80m bgl Orange and light grey slightly gravelly sandy silty CLAY (gravel is fm and sub-angular)	20	14	23.50	0.26	Overconsolidated

Liquidity Index testing revealed no evidence for moisture deficit within heavily overconsolidated sample of 6th River Terrace Deposits and two overconsolidated samples of Bagshot Formation tested.

5.2.2.2 Liquid Limit

A comparison of the soil moisture content and the liquid limit can be seen tabulated below.

Moisture Content vs. Liquid Limit				
Stratum/Trial Hole/Depth	Moisture Content (MC) (%)	Liquid Limit (LL) (%)	40% Liquid Limit (LL)	Result
6th River Terrace Deposits WS4/1.20m bgl Yellowish brown, orange and occasional light grey slightly gravelly sandy silty CLAY with traces of rootlets (gravel is fm and sub-angular)	17	37	14.80	MC > 0.4 x LL (No Significant Moisture Deficit)
Bagshot Formation WS1/1.80m bgl Orange and occasional light grey slightly gravel sandy silty CLAY (gravel is fm and sub-angular)	24	40	16.00	MC > 0.4 x LL (No Significant Moisture Deficit)
Bagshot Formation WS4/2.80m bgl Orange and light grey slightly gravelly sandy silty CLAY (gravel is fm and sub-angular)	20	39	15.60	MC > 0.4 x LL (No Significant Moisture Deficit)

The above table revealed no evidence for moisture deficit the sample of 6th River Terrace Deposits and two samples of Bagshot Formation tested.

5.2.3 Particle Size Distribution (PSD) Tests

The results of PSD testing undertaken on one granular sample of the 6th River Terrace Deposits and Bagshot Formation encountered are tabulated below.

PSD Test Results Summary			
Trial Hole/Depth/Soil Description	Volume Change Potential Range		Passing 63µm sieve Range (%)
	BRE	NHBC	
6th River Terrace Deposits WS1/1.50m bgl Orangish brown clayey very gravelly SAND (gravel is fmc and round to sub-angular)	No	No	7.7
Bagshot Formation WS2/2.50m bgl Orangish brown gravelly clayey SAND (gravel is fmc and sub-angular to sub-rounded)	No	No	13.9

NB Volume Change Potential refers to BRE Digest 240 (based on Grading test results).
Shrinkability refers to NHBC Standards Chapter 4.2 (based on Grading test results).

Volume Change Potential – BRE 240 states that a soil has a volume change potential when the clay fraction exceeds 15%. Only the silt and clay combined fraction are determined by sieving therefore the volume change potential is estimated from the percentage passing the 63µm sieve.

NHBC Standards Chapter 4.2 states that a soil is shrinkable if the percentage of silt and clay passing the 63µm sieve is greater than 35% and the Plasticity Index is greater than 10%.

5.2.4 Sulphate and pH Tests

Water soluble sulphate and pH tests were undertaken on one sample of Bagshot Formation (WS2/2.50m bgl). The water-soluble sulphate concentration was found to be 160mg/l, with a pH of 7.68.

5.2.5 BRE Special Digest 1

In accordance with BRE Special Digest 1 'Concrete in Aggressive Ground' (BRE, 2005) two samples of 6th River Terrace Deposits (WS4/1.00m and WS2/1.80m bgl) were scheduled for laboratory analysis to determine parameters for concrete specification.

The results of the chemical analysis undertaken are given within Appendix D and a summary is tabulated below.

Summary of Results of BRE Special Digest Testing			
Determinand	Unit	Minimum	Maximum
pH	-	7.6	7.7
Ammonium as NH ₄	mg/kg	1.1	1.7
Sulphur	%	<0.02	<0.02
Chloride (water soluble)	mg/kg	6	14
Magnesium (water soluble)	mg/l	1.1	1.5
Nitrate (water soluble)	mg/kg	<3	7
Sulphate (water soluble)	mg/l	14	15
Sulphate (total)	mg/kg	<200	<200

6.0 ENGINEERING CONSIDERATIONS

6.1 Soil Characteristics and Geotechnical Parameters

Based on the results of the intrusive investigation and geotechnical laboratory testing the following interpretations have been made with respect to engineering considerations.

- Made Ground was encountered from ground level in WS1 – WS3 and TP1 – TP3 and below a 0.15m thick brick paving in WS3. The soils were noted for the full depth of TP1 – TP3 and WS3 (0.50 – 1.00m bgl) and to 0.30 – 0.75m bgl in WS1, WS2 and WS4.

As a result of the inherent variability of Made Ground, it is usually unpredictable in terms of bearing capacity and settlement characteristics. Foundations should, therefore, be taken through any Topsoil and either into, or onto a suitable underlying natural stratum of adequate bearing characteristics.

Made Ground may be found to deeper depth at other locations on the site, especially close to former structures/foundations and service runs.

- Soils described as the 6th River Terrace Deposits were encountered underlying the Made Ground from 0.30 – 0.70m bgl in WS1, WS2 and WS4 to depths of between 1.60 – 2.30m bgl. The soils generally comprised orange brown/brown/blue/grey gravelly clays/clays and clayey sands over a clayey gravelly sand. The sand was fine to coarse grained and the gravel was occasional, fine to medium, sub-angular to angular flints.

Bands of cohesive material was encountered in WS1 between 0.30 – 0.70m bgl, WS2 between 1.20 – 1.80m bgl and WS4 between 1.10 – 1.60m bgl. The soils generally comprised an orange brown/brown/blue/grey mottled gravelly sandy clay. The sand was fine to coarse grained and the gravel was occasional, fine to medium, sub-angular to angular flints.

In-situ testing revealed the cohesive 6th River Terrace had a high to medium undrained shear strength (40 - 90kPa) and the granular soils were dense. The assumed cohesive 6th River Terrace Deposits from the Super Heavy Dynamic Probes was found to have a medium undrained shear strength and the granular deposits were loose to dense.

A potential soft spot was encountered in DP3 between 1.80 – 2.10m bgl, possible due to the ingress of groundwater.

The cohesive 6th River Terrace Deposits were likely to have a **low volume potential** in accordance with BRE240 and NHBC Standards Chapter 4.2. The soils were found to be very stiff. Geotechnical testing did not reveal any evidence of moisture deficits within the one sample of 6th River Terrace Deposits tested.

The granular soils were found to have **no volume change potential** in accordance with BRE240 and NHBC Standards Chapter 4.2.

The soils of the 6th River Terrace Deposits are considered to be a suitable bearing stratum for **lightly to moderately** loaded foundations. Settlements on loadings are likely to be high.

- The Bagshot Formation was noted underlying the 6th River Terrace Deposits from 1.60 – 2.30m bgl for the remainder of WS1, WS2 and WS4, depths of between 2.45 – 3.45m bgl. The soils

generally comprised an interbedded orange brown/grey/blue mottled silty clayey sand to a silty sandy clay. The sand was fine to coarse grained.

In-situ testing revealed the cohesive Bagshot Formation had a low to medium undrained shear strength and the granular soils were found to be loose to medium dense. The assumed cohesive 6th Bagshot Formation from the Super Heavy Dynamic Probes was found to have a very low undrained shear strength and the granular deposits were loose to extremely dense.

The SHDP undertaken on the cohesive soils of the 6th River Terrace Deposits and Bagshot Formation may underestimate the undrained shear strength.

A number of soft spots, possibly due to the ingress of groundwater were encountered within the Bagshot Formation and the assumed Bagshot Formation within the SHDP.

The cohesive Bagshot Formation were likely to have a **medium volume potential** in accordance with BRE240 and NHBC Standards Chapter 4.2. The soils were found to be firm to stiff.

The granular soils were found to have **no volume change potential** in accordance with BRE240 and NHBC Standards Chapter 4.2.

Geotechnical testing did not reveal any evidence of moisture deficits within the two samples of Bagshot Formation tested.

The soils of the Bagshot Formation are considered to be a suitable bearing stratum for **lightly** loaded foundations. Settlements on loadings are likely to be high.

The final design of foundations will need to take into account the volume change potential of the soil, the depth of root penetration and/or desiccation and the likely serviceability and settlement requirements of the proposed structure. These parameters for design are discussed in the next section of this report.

- Groundwater encountered during the intrusive investigation can be summarised below.

Water Strikes Encountered		
Borehole	Depth of Strike/Ingress (m bgl)	Standing Depth (m bgl)/Time
WS1	1.00 - 2.00	1.60m after 20 minutes
WS2	2.00 - 3.00	2.10m after 20 minutes
WS4		

- Roots were noted to 0.70 – 1.50m bgl in TP1 and WS1 – WS4. Traces of decayed roots were noted to 2.50m bgl in WS4, which was considered unlikely to affect serviceability.

6.2 Spread Foundations

At the time of reporting, November 2018, the proposed development was understood to comprise a retail space in the north-western corner of site, with a number of self-contained residential flats and parking spaces to the south-east. Areas of communal soft landscaping will be created along the south-western boundary for the residential flats. A plan view of the proposed development can be seen in Figure 4.

The proposed development fell within Geotechnical Design Category 2 in accordance with Eurocode 7.

The cohesive 6th River Terrace Deposits were likely to have a **low volume potential** in accordance with BRE240 and NHBC Standards Chapter 4.2. The granular soils were found to have **no volume change potential** in accordance with BRE240 and NHBC Standards Chapter 4.2.

The cohesive Bagshot Formation were likely to have a **medium volume potential** in accordance with BRE240 and NHBC Standards Chapter 4.2. The granular soils were found to have **no volume change potential** in accordance with BRE240 and NHBC Standards Chapter 4.2.

Due to the soils having volume change potential in accordance with NHBC Standard Chapter 4.2 and BRE240, foundations therefore must not be placed within cohesive root penetrated and/or desiccated soils and the influence of the trees surrounding the site must be taken into account. The base of foundation excavations must extend at least 300mm into non-root penetrated cohesive soils or onto granular soils of no volume change potential.

Foundations should bypass any Made Ground/Topsoil and take into account any potential soft spots.

Proposed foundation depths based on the depth of roots, Made Ground and groundwater ingress can be seen summarised and tabulated below.

Proposed Foundation Depths					
Borehole	Depth of Roots	Depth of Made Ground	Groundwater Depth	Foundation Depth	Strata
WS1	0.70	0.30	1.00 - 2.00, rising to 1.60m after 20 minutes	1.00	6RTD (granular)
WS2	1.00	0.70	2.00 - 3.00, rising to 2.10m after 20 minutes	1.30	6RTD (cohesive)
WS4	1.50	0.85	2.00 - 3.00, rising to 2.10m after 20 minutes	1.80	BF (granular)

Potential soft spots as a result of an ingress of groundwater were noted at DP1 (2.20 – 2.80m bgl), DP2 (3.10 – 5.00m bgl), DP3 (1.80 – 2.10m bgl and 3.70 – 4.10m bgl, DP4 (3.60 – 5.00m bgl). It was considered likely the soft spots in DP1 and DP3 were associated with groundwater ingress. The soft spots at depth may be associated with the SHDP underestimating the undrained shear strength of cohesive soils.

The following bearing capacities could be adopted for 5.0m long by 0.75m and 1.0m wide strip footings and 1.50m square pads at depths of 1.00m, 1.60m and 1.80m, based on data obtained in WS4 and DP4. The bearing capacities are tabulated overleaf.

Limit State: Bearing Capacities Calculated		
Depth (m BGL)	Foundation System	Maximum Bearing Capacity (kN/m ²)
1.00 (Cohesive 6RTD)	5.00m by 0.75m Strip	74.96
	5.00m by 1.00m Strip	76.00
	1.50m by 1.50m Pad	55.24
1.60 (Bagshot Formation)	5.00m by 0.75m Strip	191.16
	5.00m by 1.00m Strip	200.40
	1.50m by 1.50m Pad	104.61
1.80 (Bagshot Formation)	5.00m by 0.75m Strip	216.92
	5.00m by 1.00m Strip	123.32
	1.50m by 1.50m Pad	56.45
2.50 (Bagshot Formation)	5.00m by 0.75m Strip	97.63
	5.00m by 1.00m Strip	98.43
	1.50m by 1.50m Pad	99.27

Serviceability State: Settlement Parameters Calculated			
Depth (m BGL)	Foundation System	Limit Bearing Capacity (kN/m ²)	Settlement (mm)
1.00	5.00m by 0.75m Strip	70	<15
	5.00m by 1.00m Strip	70	<16
	1.50m by 1.50m Pad	50	<9
1.50	5.00m by 0.75m Strip	150	<25
	5.00m by 1.00m Strip	120	<25
	1.50m by 1.50m Pad	100	<19
1.80	5.00m by 0.75m Strip	150	<24
	5.00m by 1.00m Strip	120	<24
2.50	5.00m by 0.75m Strip	95	<13
	5.00m by 1.00m Strip	95	<14
	1.50m by 1.50m Pad	95	<10

Average Recommended Bearing Capacities	
Geology	Average Recommended Bearing Capacity (kN/m ²)
6 th River Terrace Deposits (cohesive)	75
6 th River Terrace Deposits (granular)	125
Bagshot Formation (granular)	125
Bagshot Formation (cohesive)	95

It is recommended to avoid the soft spot within WS3/DP3 (1.80 – 2.10m bgl) and either bypass or keep footings shallow and tin. A 5m long and 0.75m wide footing constructed at a depth of 1.00m bgl could be designed based on an allowable bearing capacity of 100kN/m². In case if this is not possible, the foundation is recommended to be constructed from a depth of 2.20m bgl in the vicinity of WS3/DP3.

It must be mentioned that it was assumed that excavations will be kept dry and either concreted or blinded as soon after excavation as possible. If water were allowed to accumulate on the formation for even a short time not only would an increase in heave occur resulting from the soil increasing in volume by taking up water, but also the shear strength and hence the bearing capacity would also be reduced.

Groundwater was noted to be standing in WS1, WS2 and WS4 at depths of between 1.60 – 2.10m bgl. It was therefore considered likely that groundwater would be encountered where foundations are constructed between 1.50 – 1.80m bgl. Care should be taken to not over excavate the foundations excavations beyond 1.50m bgl at the lower level of site and 2.00m bgl in the upper levels to prevent encountered groundwater.

Significant groundwater/perched water may be encountered within the Made Ground or within sand and silt bands of the 6th River Terrace Deposits and Bagshot Formation, especially after periods of prolonged rainfall.

The advice of a reputable dewatering contractor, familiar with the type of ground and groundwater conditions encountered on this site, should be sought prior to finalising the foundation design regarding the suitability and cost of dewatering to facilitate the construction of shallow foundations.

General Recommendations for Spread Foundations:

- Roots may be found to greater depths at other locations on the site, particularly close to trees and/or trees that have been removed both within the site and its close environs.
- Inspection of foundation excavations, prior to concreting, must be made by a competent and suitably qualified person to check for any soft spots and to check for the presence of roots.
- Any groundwater or surface water ingress must be prevented from entering foundation trenches. Excavations must be kept dry and either concreted or blinded as soon after excavation as possible. If water were allowed to accumulate on the formation for even a short time not only would an increase in heave occur resulting from the soil increasing in volume by taking up water, but also the shear strength and hence the bearing capacity would also be reduced and this could result in increased settlements.
- Foundation excavations must be carefully bottomed out and any loose soil or soft spots removed prior to the foundation concrete or blinding being placed. Failure to ensure that foundation excavations are suitably bottomed out could result in additional settlements.
- Foundations must not be cast over foundations of former structures and/or other hard spots.
- Isolated Pad Foundations must be at least 1.5 times the width of the widest pad apart to keep to the anticipated settlements.
- Final designs for the foundations should be carried out by a suitably qualified Engineer based on the findings of this investigation and with reference to the anticipated loadings, serviceability requirements for the structure and the developments proximity to former, present and proposed trees.

6.3 Piled Foundations

Should the bearing capacities for traditional/spread foundations not be sufficient and the ingress of groundwater proved the excavation of traditional footings to be impractical, then a piled foundation scheme may be required.

The construction of a piled foundation is a specialist job, and the advice of a reputable contractor,

familiar with the type of ground and groundwater conditions encountered on this site, should be sought prior to finalising the foundation design, as the actual pile working load will depend on the particular type of pile and method of installation adopted.

Indicative limit loads and settlements for a bored pile have been given within the table below and have been based on the SPT profile for WS3/DP3, on the basis of Classical Theory.

The bearing values may be limited by the maximum permissible stress allowable on a concrete pile.

The Classic Theory considers a Factor of Safety of ~2.5. Please note that the Total Vertical limit Load calculated is not just the accumulation of the Tip Load and Lateral Load, it incorporates a factor of safety of its own. The FOS however for the total vertical load on its own is ~2.7.

To achieve the full bearing value a pile should penetrate the bearing stratum by at least five times the pile diameter.

Bored Pile – Limit Loads and Settlement Parameters (Based on BH1/Classical Theory)						
Depth (m bgl)	Diameter (m)	Limit States (kN)			Settlement (Poulos Davis (1968))	
		Tip	Lateral	Total	Load (kN)	Total (Elastic + Rigid) (mm)
6	0.30	12.63	19.40	23.19	20	1.135
	0.45	28.42	29.10	37.64	35	1.325
	0.60	50.52	38.80	53.98	50	2.149
8	0.30	21.75	49.68	59.06	55	1.381
	0.45	48.94	74.52	95.62	95	1.591
	0.60	87.00	99.36	136.88	135	1.695

The maximum bearing values have been limited to be the maximum permissible stress allowable on the concrete piles.

The bearing values given in the table above are applicable to single piles. Where piles are to be constructed in groups the bearing value of each individual pile should be reduced by a factor of approximately 0.8 and a calculation made to check the factor of safety against block failure.

The piles will need to be designed in accordance with the volume change potential of the soils encountered, depth of desiccation, root penetration, etc. Temporary casing may be required where the upper portion of the pile passes through the Made Ground, particularly where perched water and groundwater may be encountered, to prevent necking of the concrete.

Groundwater was noted to be standing in WS1, WS2 and WS4 at depths of between 1.60 – 2.10m bgl. Therefore, it was considered likely that groundwater will be encountered during installation of the piles. This will need to be taken into account in the final design.

6.4 Excavations and Stability

Shallow excavations in the Made Ground and 6th River Terrace Deposits are likely to be marginally stable at best. Long, deep excavations, through both these strata and Bagshot Formation are likely to become unstable.

Unsupported earth faces formed during excavation may be liable to collapse without warning and suitable safety precautions should therefore be taken to ensure that such earth faces are adequately supported before excavations are entered by personnel.

6.5 Sub-Surface Concrete

For the classification given below, the “mobile” and “natural” was adopted given the geology encountered and the residential use of the site.

Made Ground

Laboratory contamination testing of the four samples of Made Ground revealed the water-soluble to range between 40 - 192mg/l with a pH range of 7.80 – 8.00.

Natural Ground – 6th River Terrace Deposits and Bagshot Formation

The water-soluble sulphates were found to range between 15 - 160mg/l (from both chemical and geotechnical tests). The total potential sulphate concentrations (3x Sulphur) were found to be <0.06% The pH ranged between 7.6 – 7.7.

Therefore, sulphate concentrations measured in 2:1 water/soil extracts taken, fell into Class DS-1 of the BRE Special Digest 1, 2005, *Concrete in Aggressive Ground*. Table C1 of the Digest indicated an ACEC (Aggressive Chemical Environment for Concrete) classification of AC-1.

Concrete to be placed in contact with soil or groundwater must be designed in accordance with the recommendations of Building Research Establishment Special Digest 1, 2005, *Concrete in Aggressive Ground* taking into account the pH of the soils.

6.6 Surface Water Disposal

A falling head test was undertaken in WS2 and WS4 at a depth of 2.20 – 2.10m bgl. The trial holes were bottomed out in the Bagshot Formation, comprising an orange brown/blue/grey mottled silty clayey sand. The sand was fine to coarse grained. The results can be seen tabulated overleaf:

Groundwater was noted to be standing in WS1, WS2 and WS4 at depths of between 1.60 – 2.10m bgl.

Falling Head Test Results					
Trial Hole/Depth of Trial Hole/ (m)	Test	Starting Water Level (m bgl)	Final Water Level (m bgl)	Time taken (mins)	Infiltration Rate (m/s)
WS2/2.10m bgl	1	0.00	0.710	63	4.80×10^{-6}
WS4/2.10m bgl	1	0.00	0.785	65	6.41×10^{-6}

The site was located within a **Secondary A Aquifer**, comprising the superficial deposits of the 6th River Terrace Deposits. The bedrock of the Bagshot Formation which may be present along the southern boundary of the site was classified as a **Secondary A Aquifer**.

Examination of the Environment Agency records showed that the site **was not** located within a Groundwater Source Protection Zone (SPZ) as classified in the Policy and Practice for the Protection of Groundwater.

Consultation with the Environment Agency must be sought regarding any use that may have an impact on groundwater resources.

The principles of sustainable urban drainage system (SUDS) should be applied to reduce the risk of flooding from surface water ponding.

6.7 Road and Hardstanding

Intrusive works revealed a Made Ground to depths of 0.30 – >1.00m bgl mantling the site. Where roads and hardstanding are to be founded in the Topsoil a CBR value of 1% could be adopted. Given that the Made Ground encountered beneath the site was a mixture of sandy, gravely, silty clay-based soils, these deposits are unlikely to be frost susceptible.

DCP testing was carried out at 2No. locations across the site to determine the equivalent CBR values of the soils underlying the site at shallow depth (0.92m bgl) in accordance with BS1377 Part 9:2016:4.3 and a summary of the results are tabulated below.

DCP Test Results Summary						
Test Location	Layer One		Layer Two		Layer Three	
	Thickness (mm)	CBR (%)	Thickness (mm)	CBR (%)	Thickness (mm)	CBR (%)
1	219 (MG)	22	525 (MG)	15	847 (MG/6RTD)	38
2	211 (MG)	12	488 (MG)	22	139 (MG/6RTD)	49

*MG – Made Ground; 6RTD – 6th River Terrace Deposits

Equilibrium CBR Assessment

Roads and hardstanding constructed on the granular 6th River Terrace Deposits should be designed based on a CBR value of 15%. This is based on reference to Table C1 of TRL1132 and average construction conditions. Based on wet conditions a CBR of 10% should be adopted, with dry conditions a CBR of 20% being applicable.

Roads and hardstanding constructed on the cohesive 6th River Terrace Deposits should be designed based on a CBR value of 4%. This is based on reference to Table C1 of TRL1132 and average construction conditions. Based on wet conditions a CBR of 2.5% should be adopted, with dry conditions a CBR of 4.5% being applicable.

Frost Susceptibility Assessment

The cohesive 6th River Terrace Deposits are clay-based soils (poorly drained) with plasticity indexes of ~20%, meaning they are likely to be **frost susceptible**.

The 6th River Terrace Deposits are poorly drained and clayey, the soils may be **frost susceptible**.

All formation levels for roads and hardstanding should be proof rolled to highlight any soft areas which should then be dug out and replaced with selected granular material compacted in thin layers to a suitable specification.

7.0 PHASE 2 CONTAMINATION RISK ASSESSMENT

7.1 Results of the Phase 1 Risk Assessment (Conceptual Site Model)

The tabulated Conceptual Site Model developed based on the Ground and Water Limited Desk Study Report (GWPR2800/DS/November 2018) has been reproduced in this section and can be seen below.

Tabulated Conceptual Site Model – Plausible Pollutant Linkages Only		
Potential Sources	Potential Absorption Pathways	Potential Receptors
On-Site Sources Contaminants introduced on-site by historic demolition and construction activities, historic use of site as an engineering works and infilled pond with unknown materials. • Heavy metals & semi-metals (incl. Arsenic, Cadmium, Chromium, Lead etc); • Combustion products (PAH's, benzo(a)pyrene, fluoranthene, dibenz(a,h)anthracene); • Organic compounds (fuel oils, ash, tar); • BTEX used as marker compounds for Volatile Organic Compounds (VOC's); • Asbestos (building material, pipe lagging).	Direct ingestion of soil and soil derived household dust; Dermal contact of soil and soil derived household dust; Ingestion of soil with elevated concentration of determinants; Dermal contact with impacted soils; Inhalation of impacted dust (indoors and outdoors) with elevated concentration of determinants; Inhalation of volatiles (indoors and outdoors) with elevated concentration of determinants.	Construction workers Service and Maintenance Operatives Site Occupiers/End-Users (Residents)
Contamination from electricity substations in the north-western of site: • PCB's	Surface water runoff; Via anthropogenic pathways; Via Made Ground (if present), Bagshot Formation.	Secondary (A) Aquifer underlying site (Bagshot Formation)

Made Ground was encountered from ground level in WS1 – WS3 and TP1 – TP3 and below a 0.15m thick brick paving in WS3. The soils were noted for the full depth of TP1 – TP3 and WS3 (0.50 – 1.00m bgl) and to 0.30 – 0.75m bgl in WS1, WS2 and WS4. The soils generally comprised a dark brown/grey silty gravelly sandy clay to a clayey gravelly sand. The sand was fine to coarse grained and the gravel was occasional, fine to coarse, sub-rounded to angular flints, brick, concrete, ceramic and tarmac fragments.

The intrusive investigation did **not** reveal any visual or olfactory evidence to suggest any hydrocarbon-type contamination in the trial holes excavated on the site. The chemical laboratory results have verified that no elevated concentrations of aliphatic/aromatic hydrocarbons (C₅-C₃₅) or BTEX compounds are present in the soils underlying the site.

Made Ground was anticipated to be on-site, consequently there was no need to modify the tabulated Conceptual Site Model.

Although, it should be noted that no deep Made Ground associated with a backfilled pond was encountered during the site investigation, therefore, the discovery strategy should be put in place.

7.2 Sampling Locations

The methodology for sampling locations can be seen tabulated below. A trial hole location plan is

given within Figure 5. A random and targeted sampling strategy was adopted.

Methodology for Sampling Locations		
Trial Holes	Sampling Strategy	Proposed End-Use
WS1	Targeted Location of historic electricity sub-station and infilled pond	Below Proposed Retail Space
WS2	Random	Below Proposed Flats
WS3		Communal Soft Landscaping
WS4		Below Proposed Flats
TP1		
TP2		
TP3		

The area investigated totals 2,000m² and with seven sampling locations, given an unknown hotspot shape, the sampling density means that a hotspot with an area of approximately 428.57m² and a radius of approximately 11.67m would be encountered (CLR 4).

Soil sampling depths were chosen to reflect the receptors of concern, human health, and typically comprised a surface or near surface sample and then at approximately 0.50m depth increments thereafter, extending into the underlying natural soils. The receptors relevant to the sampling depths can be seen below:

Near surface samples	Direct ingestion, dermal contact and dust inhalation. Protection of end-users and maintenance workers e.g. Landscape Gardeners. Protection of shallow rooted plants.
>0.5m below ground level	Protection of deep rooted plants.

7.3 Chemical Laboratory Testing

A programme of chemical laboratory testing, scheduled by Ground and Water Limited and carried out by DETS Limited, was undertaken on three samples of Made Ground (TP1/0.25m, WS1/0.25m and WS4/0.50m bgl).

Methodology for Sampling Locations and Chemical Laboratory Testing		
Trial Hole	Depth (m bgl)	Sampling Strategy
TP1	0.25	Representative sample of Made Ground
WS1	0.25	
WS4	0.50	

The depth of soil sampling can be seen within the trial hole logs presented in Appendix B.

The analysis suite is presented overpage and comprised:

- Semi Metals and Heavy Metals incl. Arsenic, Cadmium, Chromium (incl. Hexavalent Chromium), Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc (TP1/0.25m, WS1/0.25m and WS4/0.50m bgl);
- Asbestos Screen (TP1/0.25m, WS1/0.25m and WS4/0.50m bgl);
- Polycyclic Aromatic Hydrocarbons (PAHs) incl. Naphthalene, Acenaphthylene, Acenaphthene,

- Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Dibenz(a,h)anthracene, Benzo(ghi)perylene (TP1/0.25m, WS1/0.25m and WS4/0.50m bgl);
- Fuel Oils – Speciated TPH including full aliphatic/aromatic split (WS1/0.25m and WS4/0.50m bgl);
 - BTEX compounds (Benzene, Toluene, Ethylbenzene, Xylene) and MTBE – used as marker compounds for Volatile Organic Compounds (VOCs) (WS1/0.25m and WS4/0.50m bgl);
 - PCBs (WS1/0.25m bgl).

The chemical laboratory results are presented in Appendix E.

7.3.1 Soil Assessment Criteria

The derivation of Soil Assessment Criteria used within this report can be seen within Appendix F.

7.3.2 Determination of Representative Contamination Concentration

At the time of reporting, November 2018, the proposed development was understood to comprise a retail space in the north-western corner of site, with a number of self-contained residential flats and parking spaces to the south-east. Areas of communal soft landscaping will be created along the south-western boundary for the residential flats. A plan view of the proposed development can be seen in Figure 4.

The results of the chemical laboratory testing were compared to the LQM/CIEH Suitable 4 Use Levels (S4UL) for a “**Residential without homegrown produce**” land-use scenario. The C4SL LLTC for Lead was compared to a “**Residential without homegrown produce**” land-use scenario.

Where no LQM/CIEH S4UL/C4SL LLTC was available for a particular determinant then preliminary reference was made to the laboratory detection limit of the determinant. If a positive concentration was noted then further risk assessment was undertaken.

For Cyanide, where no SGC/GAC or C4SL LLTC was available a Site Specific Assessment Criteria of 10mg/kg was adopted. This is based on ICRL 59/83, TCL, ATRISK (SOIL) Screening Value and Dutch Intervention Value (ranging from 20 – 34mg/kg). Therefore, a SSAC of ~10mg/kg is considered conservative.

Where a contaminant of concern’s LQM/CIEH/S4UL/C4SL LLTC varies according to the Soil’s Organic Matter (SOM), the SOM recorded for each soil sample was used to derive the appropriate SGV/GAC. The average SOM of the samples analysed was 1.56% (SOM ranged between 0.9 – 1.9%).

Double plot analysis indicated that the majority PAH’s encountered were from a combustion source, within the urban background source and may be associated fragments of coal. None of the PAH’s appeared to be from a Coal Tar source and therefore the benzo(a)pyrene S4UL was considered suitable for use. The PAH double ratio analysis can be seen in Appendix G.

The results of the comparison of the representative contaminants concentrations are presented in the table below.

Soil Guideline Values and General Acceptance Criteria Results	
Substance	Sample Location Where available LQM/CIEH S4UL and CSL4 LLTC were exceeded for relevant land-use scenario
	"Residential without Homegrown Produce" Land-Use Scenario
Arsenic	None
Boron	None
Cadmium	None
Chromium (III)	None
Hexavalent Chromium (VI)	None
Copper	None
Lead	None
Mercury (Elemental)	None
Nickel	None
Selenium	None
Vanadium	None
Zinc	None
Cyanide (Total)	None
Total Phenol	None
Naphthalene	None
Acenaphthylene	None
Acenaphthene	None
Fluorene	None
Phenanthrene	None
Anthracene	None
Fluoranthene	None
Pyrene	None
Benzo(a)anthracene	None
Chrysene	None
Benzo(b)fluoranthene	TP1/0.25m bgl (15.90mg/kg)
Benzo(k)fluoranthene	None
Benzo(a)pyrene	TP1/0.25m bgl (8.64mg/kg)
Indeno(1,2,3-cd)pyrene	None
Dibenz(a,h)anthracene	TP1/0.25m bgl (1.21mg/kg)
Benzo(ghi)perylene	None
TPH C5 – C6 (aliphatic)	None
TPH C6 – C8 (aliphatic)	None
TPH C8 - C10 (aliphatic)	None
TPH C10 - C12 (aliphatic)	None
TPH C12 - C16 (aliphatic)	None
TPH C16 - C21 (aliphatic)	None
TPH C21 - C34 (aliphatic)	None
TPH C5 – C7 (aromatic)	None
TPH C7 – C8 (aromatic)	None
TPH C8 – C10 (aromatic)	None
TPH C10 – C12 (aromatic)	None
TPH C12 – C16 (aromatic)	None
TPH C16 - C21 (aromatic)	None
TPH C21 - C35 (aromatic)	None
Benzene	None
Toluene	None
Ethylbenzene	None
Xylene (o, m & p)	None
MTBE	None
Asbestos Screen	None

Chemical laboratory testing revealed an elevated level of benzo(b)fluoranthene, benzo(a)pyrene and dibenz(a,h)anthracene in excess of the C4SL LLTC for a ***“Residential without homegrown produce”*** land use scenario was detected in one sample of Made Ground tested (TP1/0.25m bgl).

Chemical laboratory testing of the Made Ground revealed no other elevated levels of determinants above the guideline levels for a ***“Residential without homegrown produce”*** land-use scenario.

The intrusive investigation did **not** reveal any visual or olfactory evidence to suggest any hydrocarbon-type contamination in the trial holes excavated on the site. The chemical laboratory results have verified that no elevated concentrations of aliphatic/aromatic hydrocarbons (C₅-C₃₅) or BTEX compounds are present in the soils underlying the site.

Further testing and sampling recommended to further examine the distribution of PAHs within the Made Ground. This would allow for statistical analysis of the distribution of PAHs to be undertaken and possibly remove or reduce any remediation required.

The BRE *“Cover Systems for Land Regeneration, Thickness Design of Cover Systems for Contaminated Land, BRE, March 2004”*, allows for the design of cover systems to impacted soils where the concentration of determinants within the ground does not exceed any of the respective SGVs or GACs by more than six.

Since the maximum concentration of benzo(b)fluoranthene, benzo(a)pyrene and dibenz(a,h)anthracene (15.90mg/kg, 8.64mg/kg, 1.21mg/kg) identified in the Made Ground was not over six times the relevant SGV for a ***“Residential without homegrown produce”*** land-use scenario the BRE Cover Systems could be applied.

The BRE Cover Systems spreadsheet was based on a mixing zone of 600mm. The lower the concentration of the elevated determinants in the imported Topsoil, the lesser the amount of clean cover will be required.

An **example cover thickness** has been calculated of ~504mm using an approximate assumed concentration of PAHs (0.1mg/kg) likely to be present in any imported Topsoil, which can be viewed in Appendix H. **The actual cover thickness would need to be calculated once a source of imported Topsoil was known with available chemical results certificates.**

Excavation of the soft landscaped garden areas must be independently inspected to validate that the calculated depth has been achieved **before any Topsoil is imported onto the site.**

Complete removal of affected Made Ground from the site has not been considered given the cost implications and that a simple capping system could be adopted. This would prevent needless lorry movements and prevent waste unnecessarily being sent to landfills with only a finite capacity.

7.4 Groundwater Risk Assessment

The Desk Study revealed the site to be located on **Secondary A Aquifer** relating to the bedrock deposits of the Bagshot Formation. No designation was given for superficial deposits due to their likely absence.

Examination of the DEFRA records showed that the site did not fall within a Groundwater Source Protection Zone as classified in the Policy and Practice for the Protection of Groundwater.

The nearest surface water feature was an unnamed pond ~100m east. The Emm Brook was noted ~520m south-west of site, flowing in a north-westerly direction.

From analysis of hydrogeological and topographical maps groundwater was anticipated to be encountered at moderate depth (4 - 7m below existing ground level (bgl)) and it was considered that the groundwater was flowing in a north-westerly direction in accordance with the local topography.

Examination of the Environment Agency records showed that the site fell within a **Flood Zone 1** (an area with a low probability of river or sea flooding).

Given the hydrogeological setting of the site, the Secondary A Aquifer directly underlying the site was considered to be a sensitive receptors. However, given the low levels of determinants noted in the soils and the likely limited mobility of determinants, the Made Grounds encountered onsite was unlikely to pose a risk to groundwater. Therefore, it was concluded that no remediation to soils was required to protect groundwater/controlled waters.

7.5 Re-Evaluated Phase 2 Conceptual Site Model

Following completion of the Phase 2 Site Investigation, the CSM within Section 7.1 of this report was re-evaluated and can be seen overleaf. The plausible pollutant linkages remaining after risk assessment are shown and where risk assessment has indicated no unacceptable risk to sensitive receptors, the pollutant linkages have been crossed out.

Tabulated Conceptual Site Model – Plausible Pollutant Linkages Only		
Potential Sources	Potential Absorption Pathways	Potential Receptors
On-Site Sources Contaminants introduced on-site by historic demolition and construction activities, historic use of site as an engineering works and infilled pond with unknown materials. • Heavy metals & semi-metals (incl. Arsenic, Cadmium, Chromium, Lead etc); • Combustion products (PAH's, benzo(a)pyrene, fluoranthene, dibenz(a,h)anthracene); • Organic compounds (fuel oils, ash, tar); • BTEX used as marker compounds for Volatile Organic Compounds (VOC's); • Asbestos (building material, pipe lagging). Chemical laboratory testing revealed an elevated level of benzo(b)fluoranthene, benzo(a)pyrene and dibenz(a,h)anthracene.	Direct ingestion of soil and soil derived household dust; Dermal contact of soil and soil derived household dust; Ingestion of soil with elevated concentration of determinants; Dermal contact with impacted soils; Inhalation of impacted dust (indoors and outdoors) with elevated concentration of determinants; Inhalation of volatiles (indoors and outdoors) with elevated concentration of determinants.	Construction workers Service and Maintenance Operatives Site Occupiers/End-Users (Residents)
Contamination from electricity substations in the north-western of site: • PCB's	Surface water runoff; Via anthropogenic pathways; Via Made Ground (if present), Bagshot Formation.	Secondary (A) Aquifer underlying site (Bagshot Formation)

Chemical laboratory testing of the Made Ground present revealed elevated levels of a number of PAHs (incl. benzo(b)fluoranthene, benzo(a)pyrene and dibenz(a,h)anthracene) above the **"Residential without Homegrown Produce"** land-use scenario.

The intrusive investigation did **not** reveal any visual or olfactory evidence to suggest any hydrocarbon-type contamination in the trial holes excavated on the site. The chemical laboratory results have verified that no elevated concentrations of aliphatic/aromatic hydrocarbons (C₅-C₃₅) or BTEX compounds are present in the soils underlying the site.

No deep Made Ground associated with a backfilled pond was encountered during the site investigation, therefore, the discovery strategy should be put in place.

Given the low levels of determinants noted in the soils and the likely limited mobility of determinants, the Topsoil encountered onsite was unlikely to pose a risk to groundwater, it was concluded that no remediation to soils was required to protect groundwater/controlled waters.

Given the limited thicknesses of Made Ground across the site, a ground-gas risk was not considered to be present on-site.

Further testing and sampling is recommended in the areas of proposed soft landscaping to further examine the distribution of PAH's within the Made Ground. This would allow for statistical analysis of the distribution of PAH to be undertaken and possibly remove or reduce any remediation required.

An **example cover thickness** has been calculated of ~504mm using an approximate assumed concentration of PAHs (0.1mg/kg) likely to be present in any imported Topsoil, which can be viewed in Appendix G. **The actual cover thickness would need to be calculated once a source of imported Topsoil was known with available chemical results certificates.**

7.8 Discovery Strategy

There may be areas of contamination that have not been identified during the course of the intrusive investigation. For example, there may have been underground storage tanks (UST's) not identified during the Ground Investigation for which there is no historical or contemporary evidence.

Such occurrences may be discovered during the demolition and construction phases for the redevelopment of the site.

Groundworkers should be instructed to report to the Site Manager any evidence for such contamination; this may comprise visual indicators, such as fibrous materials within the soil, discolouration, or odours and emission. Upon discovery advice must be taken from a suitably qualified person before proceeding, such that appropriate remedial measures and health and safety protection may be applied.

Should a new source of contamination be suspected or identified then the Local Authority will need to be informed.

7.9 Waste Disposal

The excavation of foundations is likely to produce waste which will require classification and then recycling or removal from site.

Under the Landfill (England and Wales) Regulations 2002 (as amended), prior to disposal all waste must be classified as;

- Inert;
- Non-hazardous, or;
- Hazardous.

The Environment Agency's Hazardous Waste Technical Guidance (WM3) document outlines the methodology for classifying wastes.

Once classified the waste can be removed to the appropriately licensed facilities, with some waste requiring pre-treatments prior to disposal.

Based on a risk phrase analysis of the remaining chemical laboratory test results, in accordance with EC Hazardous Waste Directive and undertaken by Ground and Water Limited, three samples of Made Ground (TP1/0.25m, WS1/0.25m and WS4/0.50m bgl) tested were classified as **NON-HAZARDOUS**. The results can be seen in Appendix I.

It is important to note that whilst we consider our in-house assessment tool to be an accurate interpretation of the requirements of WM3, therefore producing an initial classification in accordance with the guidance, landfill operators have their own assessment tools and can often come to different conclusions. As a result, some landfill operators could refuse to take apparently suitable waste. It is recommended that the receiving landfill views the results of this assessment and the chemical laboratory results to determine their own classification.

Following this initial waste hazard assessment, a Full WAC Solid Suite Test with single batch leachate was undertaken on one sample of the Topsoil (WS2/0.25m bgl) to determine which landfill category the waste conformed to. The results of the WAC test can be seen in Appendix E. **The sample fell into the INERT waste category.**

7.10 Imported Materials

Any soil which is to be imported onto the site must undergo chemical analysis to prove that it is suitable for the purpose for which it is intended.

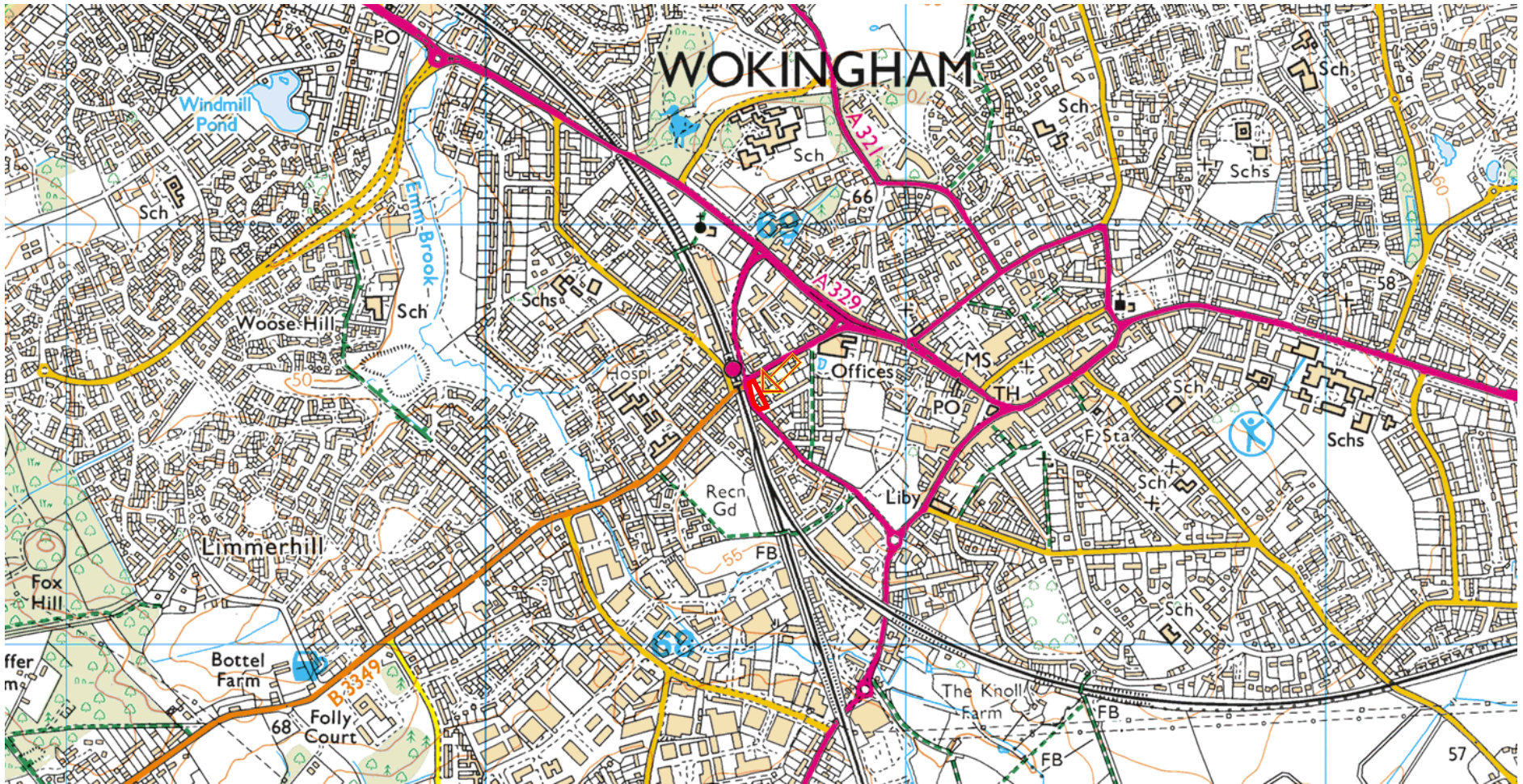
The Topsoil must be fit for purpose and must either be supplied with traceable chemical laboratory test certificates or be tested, either prior to placing (ideally) or after placing, to ensure that the human receptor cannot come into contact with compounds that could be detrimental to human health. The compounds that are to be tested for are those given in the LQM CIEH Generic Assessment Criteria, which can be viewed in Appendix F of this report.

7.11 Duty of Care

Groundworkers must maintain a good standard of personal hygiene including the wearing of overalls, boots, gloves and eye protectors and the use of dust masks during periods of dry weather.

To prevent exposure to airborne dust by both the general public and construction personnel the site should be kept damp during dry weather and at other times when dust were generated as a result of construction activities.

The site should be securely fenced at all times to prevent unauthorised access. Washing facilities should be provided and eating restricted to mess huts.



APPROXIMATE SITE BOUNDARY

NOT TO SCALE

Project:
Land adj. to Station Furniture, 46 Station Road, Wokingham RG40 2AE

Client:
Wokingham Housing Limited

Site Location Plan

Date:
November 2018

Ref:
GWPR2800

Figure 1

ground&water



APPROXIMATE SITE BOUNDARY

NOT TO SCALE

Project:

Land adjacent to Station Furniture, 46 Station Road, Wokingham RG40 2AE

Client:

Wokingham Housing Limited

Date:

November 2018

Site Development Area

Ref:

GWPR2800

Figure 2

ground&water



NOT TO SCALE

APPROXIMATE SITE BOUNDARY



Project:
Land adjacent to Station Furniture, 46 Station Road, Wokingham RG40 2AE

Client:
Wokingham Housing Limited

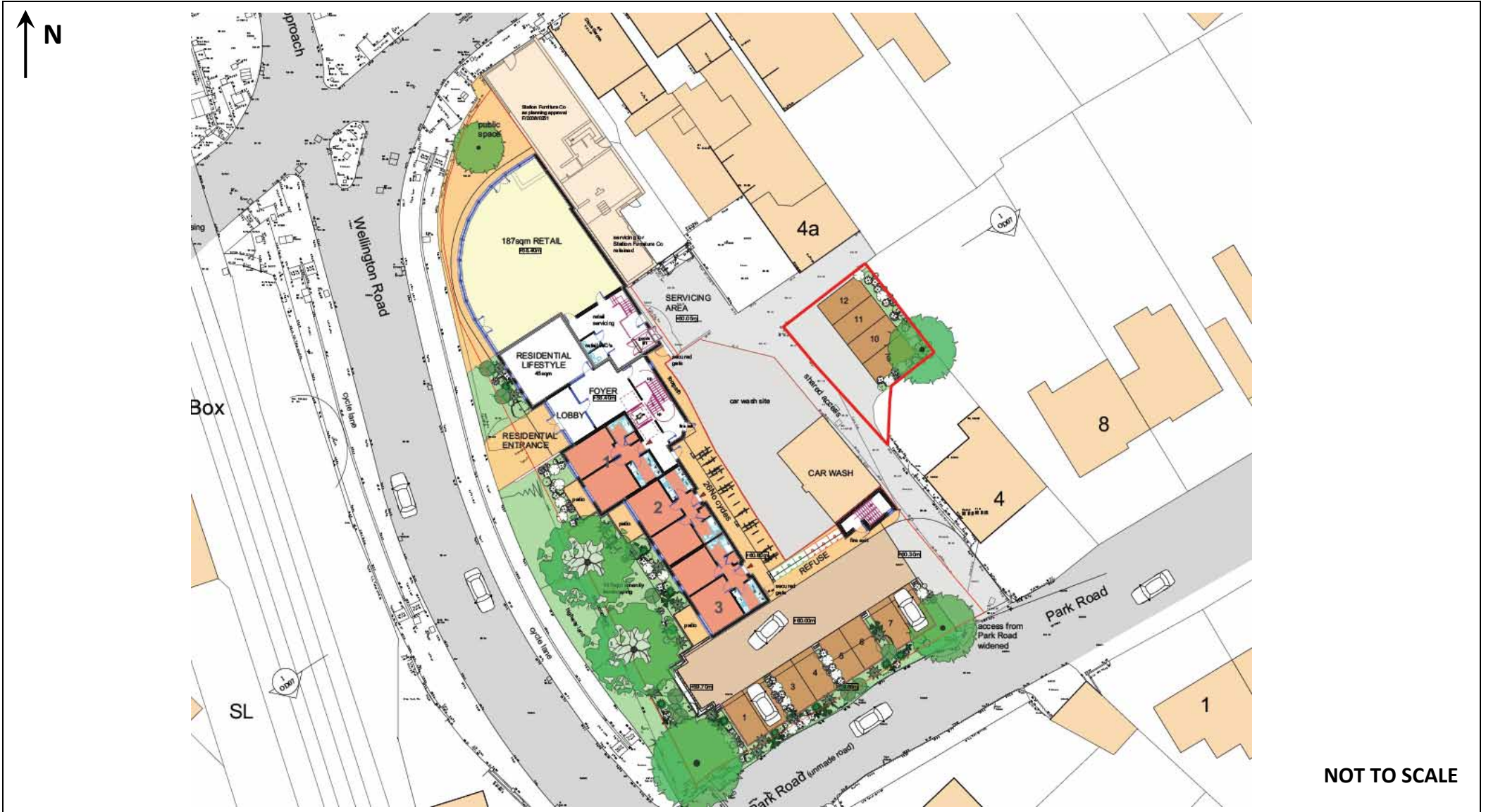
Aerial View of the Site

Date:
November 2018

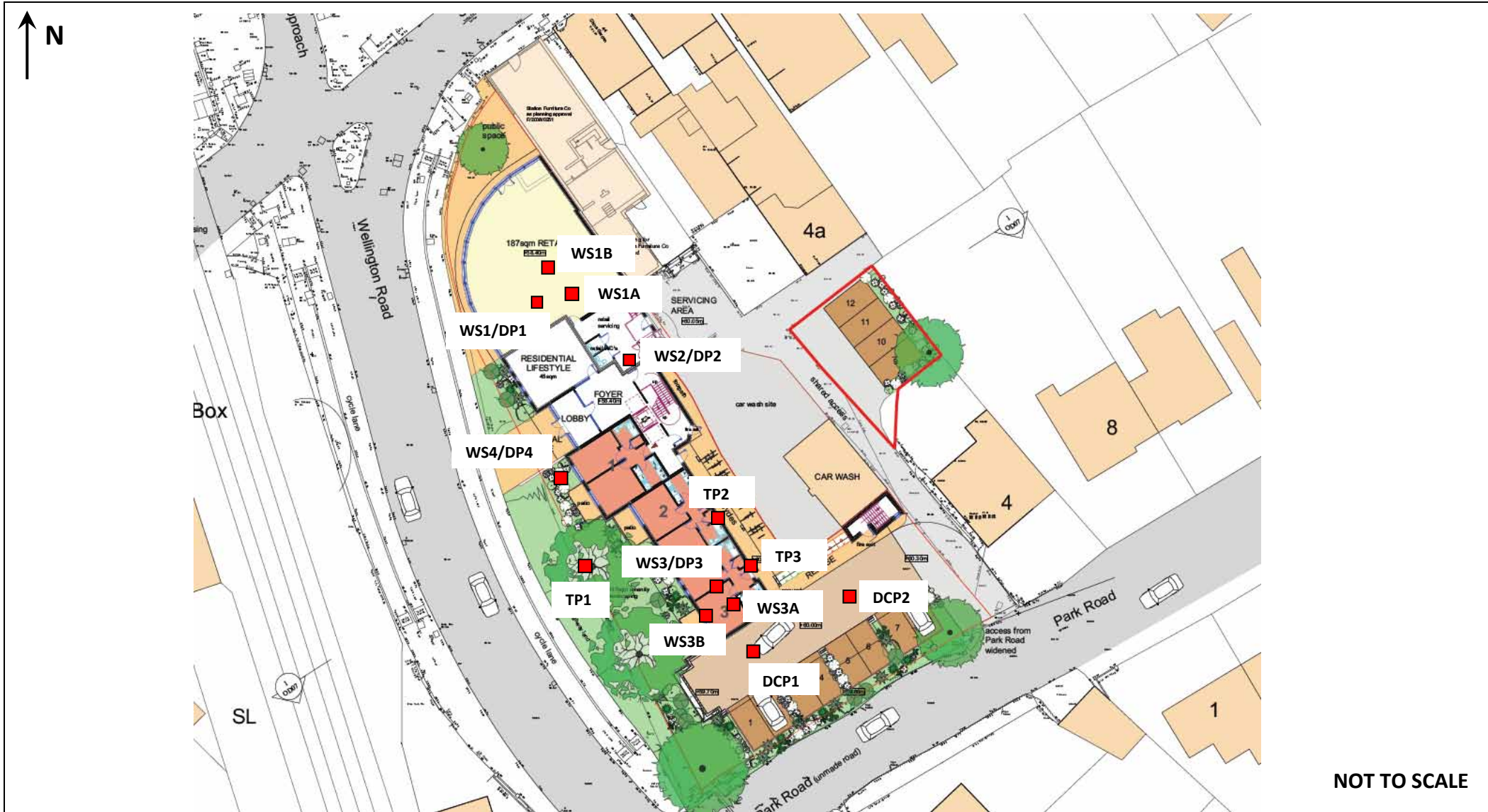
Ref:
GWPR2800

Figure 3

ground&water



Project: Land adjacent to Station Furniture, 46 Station Road, Wokingham RG40 2AE		Figure 4 
Client: Wokingham Housing Limited	Date: November 2018	
Proposed Development Plan	Ref: GWPR2800	



Project:		Figure 4 
Land adj. to Station Furniture, 46 Station Road, Wokingham RG40 2AE		
Client:	Date:	
Wokingham Housing Limited	November 2018	
Proposed Development Plan	Ref:	
	GWPR2800	