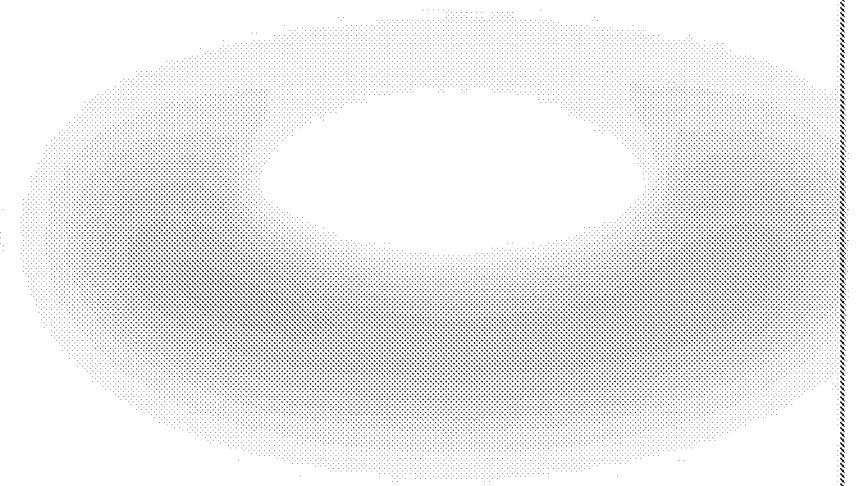




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Project: Surface Water Drainage Strategy (SWDS) & Phase 1 Flood Risk Assessment (FRA)
Prepared for: Fed3 Projects Ltd
Reference: 3834 SWDS & FRA
Date: July 2018
Version: Final v1.0



Document Issue Record

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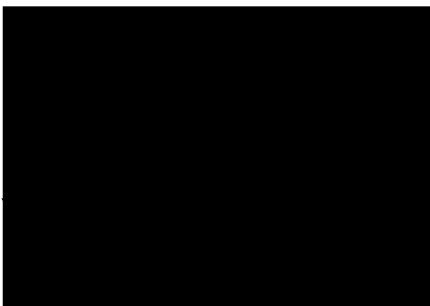
Site Location: Land at the corner of Water Lane and Dapper's Lane, Angmering, BN16 4EN

Proposed Development: Construction of a 70-bed care home.

No.		Issue	Resolution
		[Redacted Table Content]	

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1. Summary

SITE DETAILS			
Site Name	Land at the corner of Water Lane and Dapper's Lane, Angmering BN16 4EN		
Total Site Area	0.720 ha		
Site Area which is positively drained	0.326 ha		
Open Space	0.394 ha		
Predevelopment Use	Brownfield site		
Site Information	- Superficial Deposits – Head: clay, sand, silt and gravel		
	- Bedrock Geology – London Clay and Lambeth Group		
	- Superficial Hydrogeology – Secondary (undifferentiated) Aquifer		
	- 2.5mBGL Groundwater Table Depth		
	- Site Contamination – Lead, BaP, Hydrocarbons (C ₂₀ H ₁₂ & C ₂₂ H ₁₄)		
IMPERMEABLE AREAS			
	EXISTING	PROPOSED	DIFFERENCE (Proposed - Existing)
Impermeable Area (Ha)	0.116 ha	0.326 ha	+0.210 ha
Drainage Method (Infiltration/Sewer/Watercourse)	N/A	infiltration	
PROPOSED TO DISCHARGE SURFACE WATER VIA			
	YES	NO	EVIDENCE
Infiltration	X		Good potential for infiltration SuDS. Subject to BRE365 infiltration testing.
To Watercourse	X		In absence of infiltration, discharges to the ditch bounding the site.
To Surface water sewer		X	no surface water present
Combination of Surface & Foul			
PEAK DISCHARGE RATES			
	Greenfield Rates* (l/s)	Predevelopment Rates (l/s)	Proposed Rates (l/s) [+40% CC] **
Greenfield QBAR	1.2 l/s	N/A	N/A
1 in 1	1.0 l/s	15.7 l/s	1.0 l/s
1 in 30	2.6 l/s	30.8 l/s	2.6 l/s
1 in 100	3.7 l/s	30.9 l/s	3.7 l/s
SITE STORAGE VOLUME			
Source Control Provided	Yes		
Attenuation Volume (Storage - 1 in 100 year + CC)	Minimum Storage in Permeable Pavement – 47m ³		
Volume to control discharge rate	Minimum Storage in Geocellular Tank – 118 m ³		
PROPOSED DRAINAGE COMPONENTS			
Permeable Pavement	Pervious surfaces provide a surface suitable for pedestrian and/or vehicular traffic, while allowing rainwater to infiltrate through the surface and into underlying layers.		
Geocellular System	Geocellular systems can be used to control and manage rainwater surface water runoff as a storage tank. The modular/honeycomb nature of geocellular systems means that they can be tailored to suit the specific requirements of any site.		

*For the area associated with post-development total impermeable area of approximately 0.326ha. The open spaces would drain to existing ditch south of the site, as per the existing topography.

**To be referred to only if a detailed assessment of runoff discharges by infiltration concludes that infiltration solutions are unfeasible for the proposed site.

DESIGN CHECKS		
Key Drainage component	Permeable Pavement & Geocellular System	
Drainage Systems Maintenance	Supplier must provide appropriate guidance for maintenance	
All SuDS storage located outside Q100 floodplain	Yes	
Provision for blockage / Design Exceedance	Yes	Exceedance routes are provided
Time taken for 50% of storage to drain down	<24hr for all SuDS components	

2. Introduction

- 2.1 This Surface Water Drainage Strategy and Flood Risk Assessment has been prepared by Ambiental Technical Solutions, in respect of a planning application for the proposed development on land at the corner of Dapper's Lane (running north-south) and Water Lane (running approximately northeast to southwest), Angmering, West Sussex. See *Figure 1 – Site Location* below.

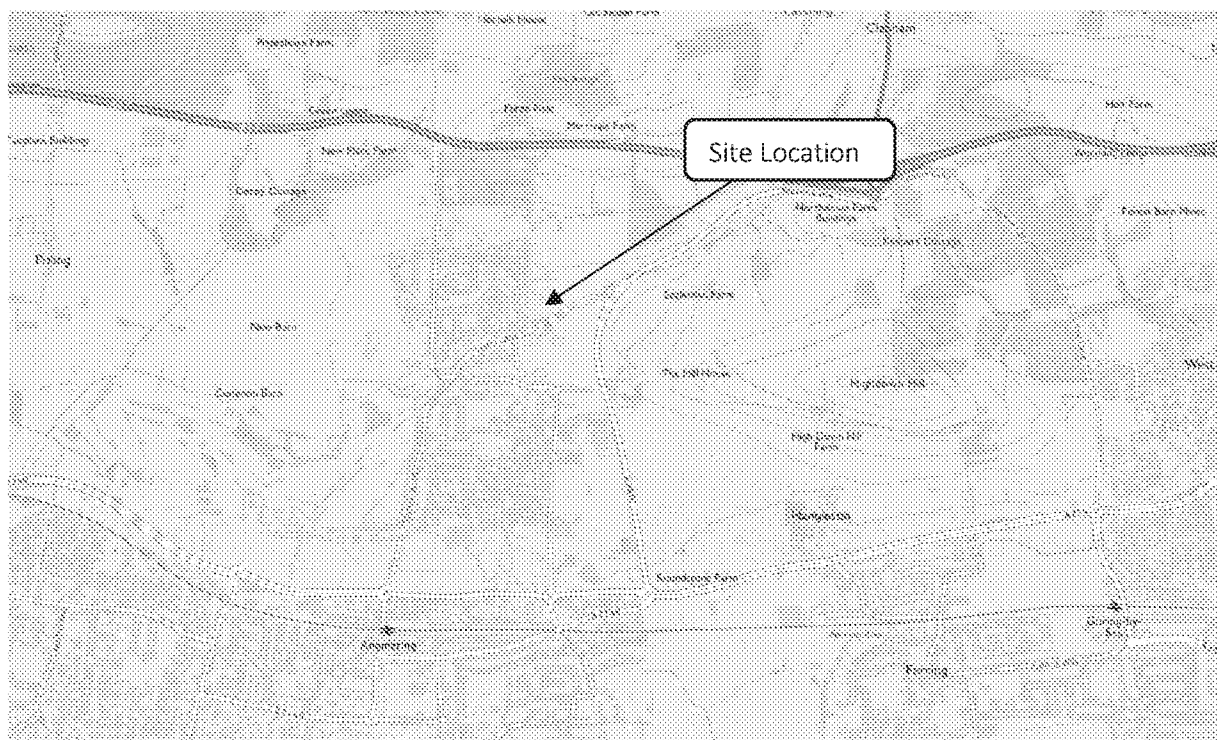


Figure 1 – Site Location (Source: OS)

Development Proposal

- 2.2 Planning permission was previously granted on the site, for 53 care apartments, comprising 4 buildings. The applicant is now seeking full planning permission for the construction of a 70 bed care home on part of the site, as a replacement to building 4, leaving the remainder of the site as permitted. A detailed drainage strategy for the wider site is required by planning condition and is in the process of being prepared, using the principles in the strategy discussed below.
- 2.3 This study is based on the plans in *Appendix 1 – Supporting Information*. The site layout was modified in-house for the purposes of this report (see *Appendix 4 – Proposed Surface Water Drainage Strategy*).

Need for Study

- 2.4 The purpose of this assessment is to demonstrate that the development proposal outlined above can be satisfactorily accommodated without worsening flood risk for the area and without placing the development itself at risk of flooding, as per National guidance provided within the National Planning Policy Framework (NPPF).

3. Site Area

- 3.1 The site is bounded to the north by several private properties, to the east by an agricultural field, by Water Lane road to the south and Dapper's Lane to the west. The site's proposed access is from Dapper's Lane.



Figure 2 - Wider Location Map. (Source: Google Earth)

- 3.2 The total area of the site is approximately 7200m² (0.72 ha). Existing impermeable areas are associated with the existing structures and other hardstanding areas, with a total area of approximately 1160m² (0.116 ha).
- 3.3 Following development, the total impermeable site area (allowing for the access road and roof) will increase to approximately 3260m² (this assumes all external paved areas will be of a permeable construction and as such self-draining).
- 3.4 The topography across the site is highest to the north-western (NW) site corner with levels at approximately 16mAOD. From the NW corner, the site slopes downward at approximately 1/100 to the east (parallel to the site's northern boundary, toward the agricultural field) and at approximately 1/20 to the south (parallel to the site's western boundary, toward Water Lane). The lowest levels are found at the junction of Water Lane with Dapper's Lane, at approximately 9.2mAOD. See Topographic Survey in *Appendix 1 – Site Information*.

Vulnerability classification

-

Sequential Test/Exception Test

- ambiental

Flood Risk Vulnerability and Flood Zone 'Compatibility' Table						
Flood Risk Vulnerability Classification		Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone	Zone 1	✓	✓	✓	✓	✓
	Zone 2	✓	✓	Exception Test Required	✓	✓
	Zone 3a	Exception Test Required	✓	✗	Exception Test Required	✓
	Zone 3b Functional Floodplain	Exception Test Required	✓	✗	✗	✗

Table 1: The Sequential Test: Flood Risk Vulnerability and Flood Zone 'Compatibility' Table as specified by NPPF.
Please note: ✓ means development is appropriate; ✗ means the development should not be permitted.

- 4.6 Using the principles of the Sequential Test outlined above, the proposed development is "More Vulnerable" and located within Flood Zone 1 (as defined by the EA Flood Map for Planning).

Site Flood Hazards

Sources of Flooding

- 4.7 As outlined in *Figure 3*, the proposed development is located within Flood Zone 1 (Low Risk of flooding) and is considered to be "More Vulnerable" under the NPPF. Communication with the EA has identified the following potential sources of flooding to the site:

Flood Sources Summary	
Source	Description
Fluvial	Black Ditch Extension
Surface	On site
Groundwater	On site
Sewer	N/A

Table 2: Summary of flood sources

Mechanisms and History of Flooding

- 4.8 According to the low detail, national-scale flood mapping created on behalf of the EA, the probability of fluvial flooding across the majority of the site is less than 0.1% annually (less than 1:1000). *Figure* outlines only the potential floodplain; and the mitigating effects of any flood defences currently in place are not considered. However, the EA have confirmed the area does not benefit from flood defences at this time.
- 4.9 Surface water flooding occurs predominantly at topographic depressions where the runoff from the wider region accumulates and ponds. Along flow pathways, increased speeds of large volumes of water runoff augment the hazard of flooding to people and may cause severe damages to property.
- 4.10 Groundwater flooding is also predominantly caused by intense and unremitting rainfalls events, however the soil layer texture and standing water table of a region are the main catalysts determining the occurrence probability and intensity of this source of flooding.

River (Fluvial)

- 4.11 The EA Flood Map for Planning (*Figure 3*) confirms that the development lies within Flood Zone 1 (Low Risk).
- 4.12 The nearest watercourse to the site is the Black Ditch Extension, which is a tributary of the River Arun, and is classed as a Main EA River. Due to the natural meandering of the Black Ditch Extension, at this location the edge of the river is located between 30m and 73m from the southern boundary of the site.
- 4.13 The Black Ditch Extension runs parallel to southern side of Water Lane. This watercourse then becomes culverted approximately 50m south west of the site and flows west in the culvert for approximately 500m below Water Lane.
- 4.14 There also appears to be ditch along the southern edge of the site. Local records show this is culverted below Water Lane (before the junction with Dappers Lane) before tying into the Black Ditch Extension.
- 4.15 Arun District Council SFRA (2017) indicates that the culverted Black Ditch extension overflowed twice in 1980, and again in 1981, causing flooding along Water Lane, approximately 50m west of the site. This was due to heavy rain and blockages in the drainage/culvert network.

Surface Water (Pluvial)

- 4.16 The EA Risk of Flooding from Surface Water map (*Figure*) shows the majority of the site to be within a 'Very Low' risk of flooding from surface water, with a less than 0.1% chance of flooding from this source annually.
- 4.17 There is a very small area of 'Low' risk of flooding located within the site boundary with an annual probability of flooding between 0.1% - 1%. This 'Low' risk area is located close to the western boundary of the site (*Figure 4*). Dapper's Lane, which is located outside of the site boundary but forms the external access road to the site, is shown to have a 'High' risk of flooding from this source, meaning areas of Dapper's Lane has a greater than 3.3% chance of flooding from surface water sources annually.
- 4.18 The EA surface water "high risk" map (*Figure 5*) shows that in a high risk scenario (>3.3% annual probability) the site is not predicted to flood. Dapper's Lane may experience flood depths of up to 300mm.
- 4.19 The EA surface water "low risk" map (*Figure 6*) shows that in a low risk scenario (0.1%-1% annual probability) the majority of the site is not predicted to flood. Overland flow routes to the western edge of site may experience flood depths of up to 300mm. Dapper's Lane may experience flood depths of up to 300mm immediately adjacent to the site, and flood depths of 300mm to 900mm further north.
- 4.20 The Arun District Council SFRA (2017) cites surface water flooding incidents in Angmering Village (Water lane) in 1980 and 1981. In 2008, there was surface water flooding predominantly to the north of Angmering due to heavy rainfall.
- 4.21 The Arun District Council SFRA (2017) indicates a historical surface water flooding incident 100m east of site on Water Lane (*Figure 7*). It is not known when this occurred. There is no record of surface water flooding incidents at the proposed site.

4.22 As such, the risk of surface water flooding to the site is deemed to be **relatively low**, with the risk of surface water flooding in the area immediately adjacent to the site on Dapper's Lane deemed to be **low to moderate**.

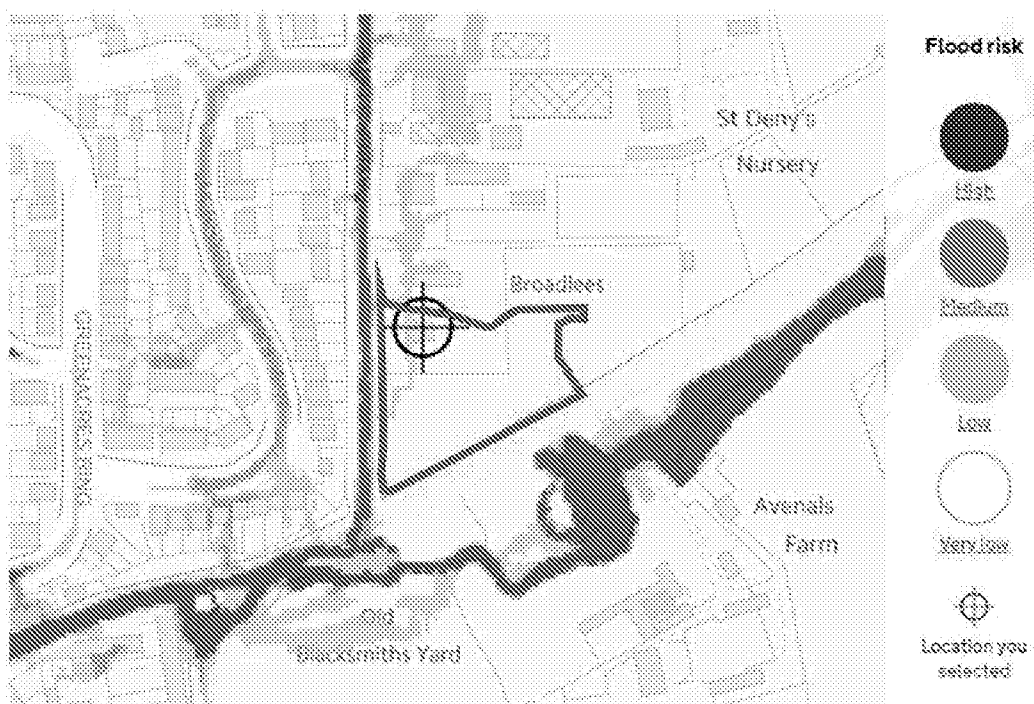


Figure 4 - EA Surface Water Flood Risk Map with site boundary shown in red (Source: EA)

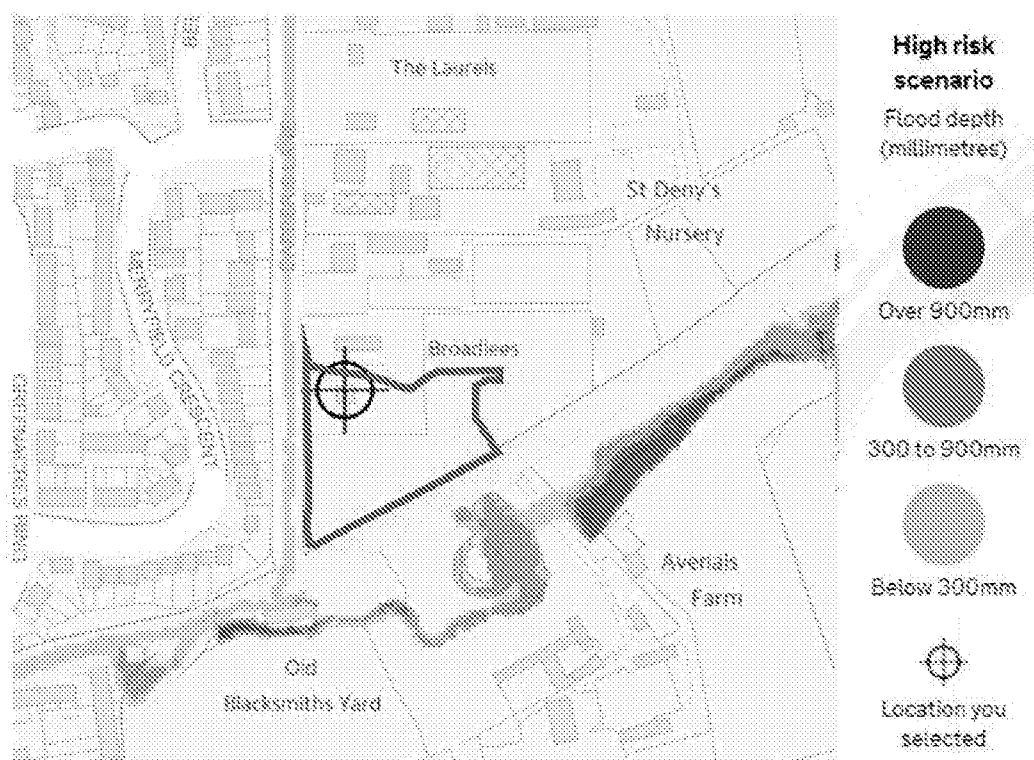


Figure 5 - EA Surface Water Depth Map (high risk scenario) with site boundary shown in red (Source: EA)

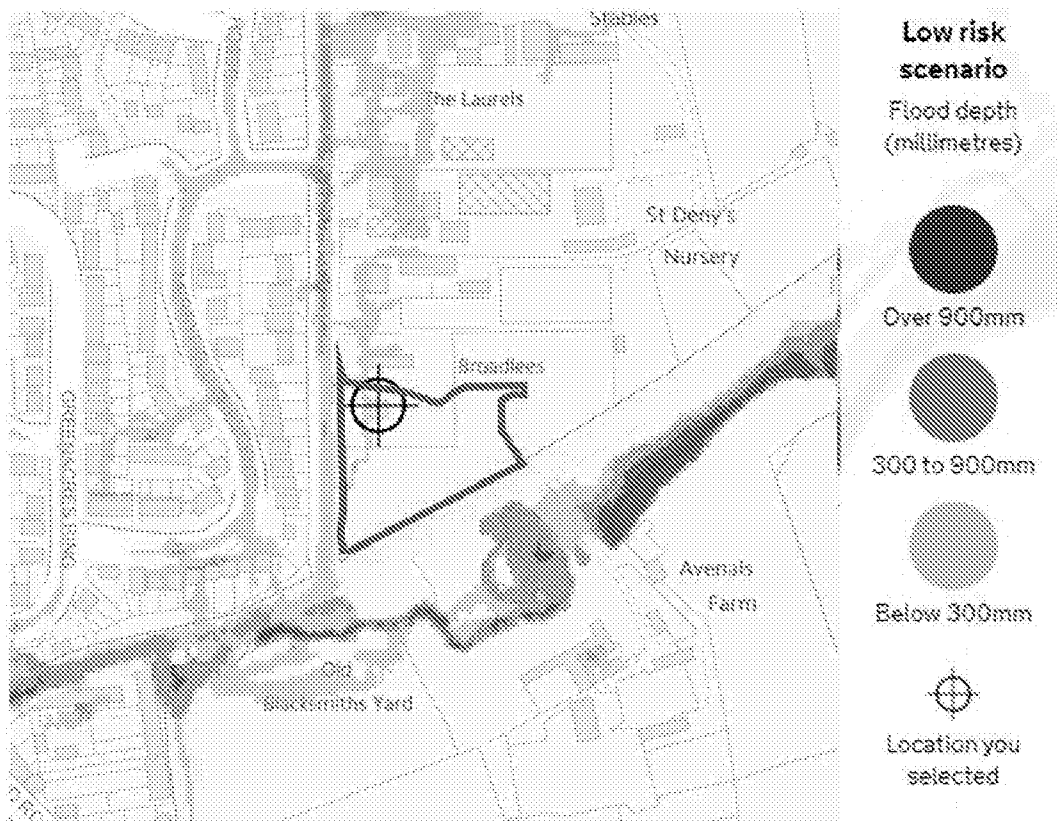


Figure 6 - EA Surface Water Depth Map (low risk scenario) with site boundary shown in red (Source: EA)

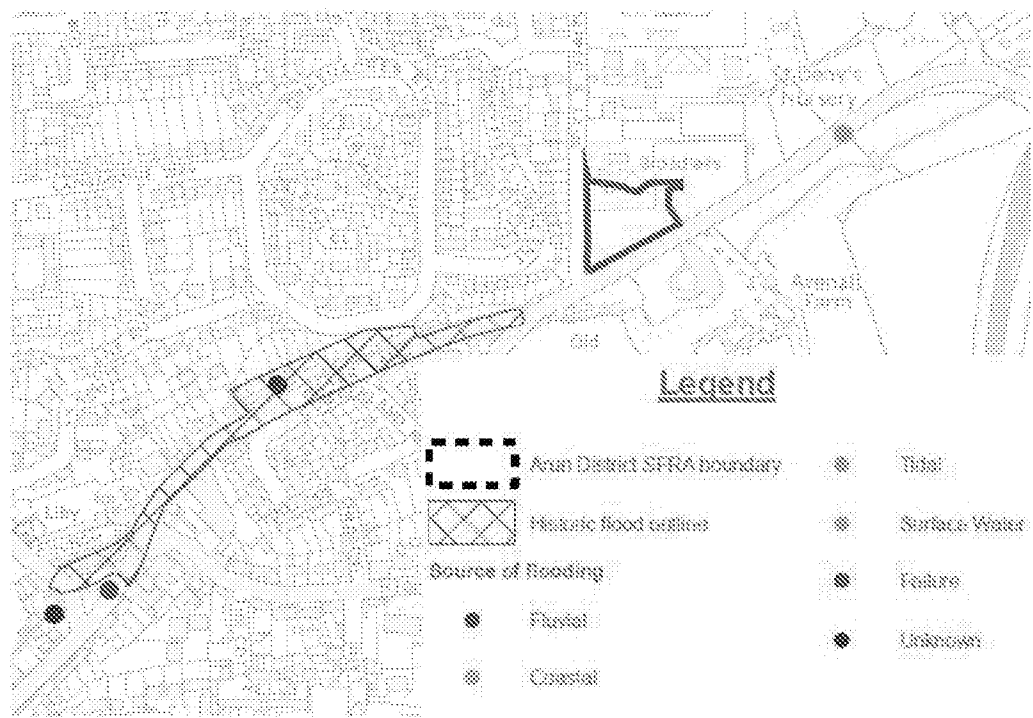


Figure 7 - Historic flooding incidents include surface water flooding incident east of site. Site boundary marked in red. (source: Arun District Council SFRA (2017))

Groundwater

- 4.23 DEFRA's¹ Geology and Soils map (Magic Map) indicates that neither the London Clay nor Lambeth Group bedrock underlying the site is water-bearing. The site is not in a groundwater source protection zone.
- 4.24 DEFRA's Geology and Soils map indicates that the superficial glacial Head deposits underlying the site are known to be water-bearing and comprise an undifferentiated Secondary Minor aquifer of intermediate vulnerability.
- 4.25 A geotechnical survey performed by Listers in 2015 (*Appendix B – Site Geology*), which includes trial pits and boreholes, confirms that the superficial Head deposits are water-bearing on site.
- 4.26 Southern Water (May 2018) have erected signage indicating a recent groundwater flooding incident at the intersection of Dapper's Lane and Water Lane, at the south-west perimeter of the site.
- 4.27 Arun District Council SFRA (2017) indicates that the vicinity of the site has a 25%-50% susceptibility to groundwater flooding (*Figure 8*).
- 4.28 As such the risk of flooding from this source to the development site is deemed **moderate**.

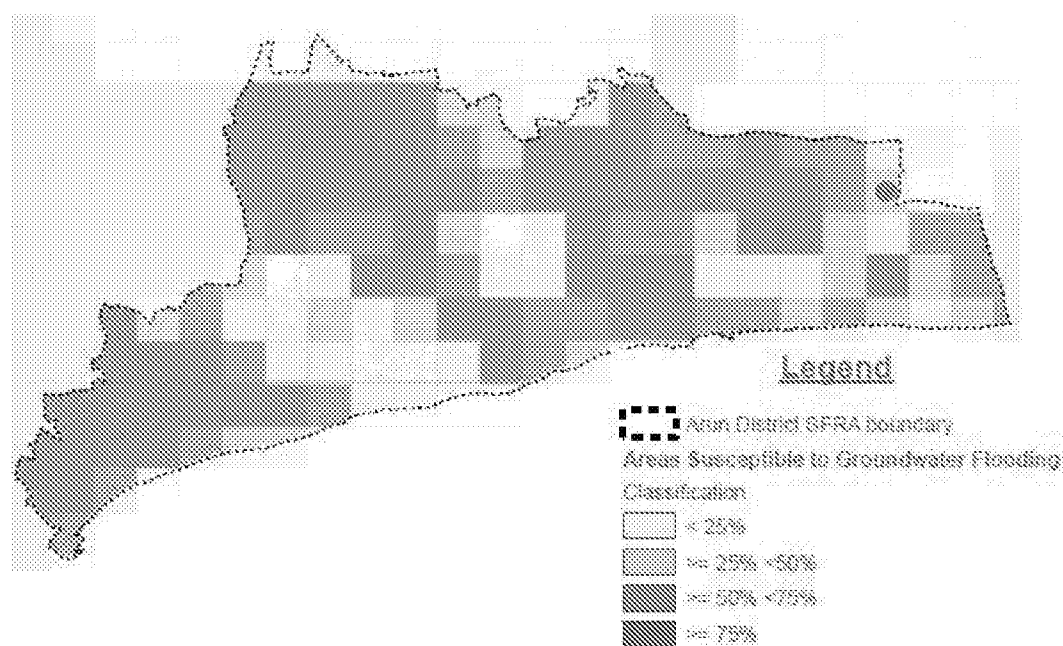


Figure 8 - Areas Susceptible to Groundwater Flooding (source: Arun District Council SFRA (2017). Green dot marks site location

¹ Department of Environment, Fisheries and Rural Affairs (DEFRA)

Sewer

- 4.29 Arun District Council SFRA (2017) shows that for postcode BN16 4**, in which the site is located, there have been 2 incidents of sewer flooding in the 10 years preceding 2016 (*Figure 9*). There is no indication that either of these incidents occurred at or particularly near the site location.
- 4.30 As such, the risk of sewer flooding to the site post development is deemed to be **relatively low**.

Post Code	Recorded Flood Incidents	Post Code	Recorded Flood Incidents
BN12 5	10	PO20 3	11
BN12 6	1	PO21 1	2
BN16 1	14	PO21 2	8
BN16 2	13	PO21 3	30
BN16 3	4	PO21 4	20
BN16 4	2	PO21 5	22
BN17 5	22	PO22 0	15
BN17 6	3	PO22 6	27
BN17 7	7	PO22 7	36
BN18 0	20	PO22 8	12
BN18 9	8	PO22 9	28
Total: 315			
Note: Based on information exported on 25/02/16			

Figure 9 – Extract image : Sewer Flooding incidents by Postcode (Source: Arun District Council SFRA (2017), based on DG5 register)

Records of Historical Flooding

- 4.31 Arun District Council SFRA (2017) demonstrates that on Water Lane, 50m west of site, there were two incidents of fluvial flooding in 1980 and one incident in 1981, associated with blockage and overflow of the culverted Black Ditch Extension during periods of heavy rainfall.
- 4.32 Arun District Council SFRA (2017) indicate only two incidents of sewer flooding for postcode BN16 4** in the 10 years preceding 2016. There is no indication that either of these sewer flooding incidents were at or near the site.
- 4.33 Arun District Council SFRA (2017) indicates that the vicinity of the site has 25%-50% susceptibility to groundwater flooding. However, there are no specific recorded incidents of groundwater flooding at or particularly near the site.

Probability of Flooding

- 4.34 According to the low detail, national-scale flood mapping created on behalf of the EA the annual probability of fluvial flooding for the site is low (less than 0.1%). The site is entirely located within Flood Zone 1, see described in *Table 3*.

Definition of NPPF Flood Zones	
Zone	Description
1	Low Probability. This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).
2	Medium Probability. This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% – 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% – 0.1%) in any year.
3a	High Probability. This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.
3b	The Functional Floodplain. This zone comprises land where water has to flow or be stored in times of flood. SFRA's should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the EA, including water conveyance routes).

Table 3: Definition of the NPPF Flood Zones. (Source: EA)

Climate Change on Site

- 4.35 Climate change is likely to increase the flow in rivers, raise sea levels and increase storm intensity. EA climate change guidance as of February 19th, 2016 identifies that flood risk from fluvial and rainfall will increase over time from the effects of climate change.
- 4.36 The risk of flooding to the site would therefore be expected to increase following the effects of climate change. The likely increases in peak rainfall intensity would also lead to an increased risk of surface water flooding.

Residual Risks

Identification of Residual Risks

- 4.37 Residual risks are those remaining after applying the sequential approach to the location of development and taking mitigating actions. Examples of residual flood risk include:
- the failure of flood management infrastructure such as a breach of a raised flood defence, blockage of a surface water conveyance system, overtopping of an upstream storage area, or failure of a pumped drainage system;
 - failure of a reservoir, or;
 - a severe flood event that exceeds a flood management design standard, such as a flood that overtops a raised flood defence, or an intense rainfall event which the drainage system cannot cope with.
- 4.38 Analysis of the EA Risk of Flooding from Reservoirs map shows the site to be located outside of any maximum flood extents due to the failure of reservoirs.
- 4.39 As such the only remaining residual risk to the site is that of drainage failure.

4.40 The site is currently largely Greenfield and as such the residual risk of sewer failure will be addressed as part of the planning application in discussion with the local water companies as part of connection consent.

4.41 As such the residual risk from drainage failure to the site is deemed likely to be **not significant**.

Flood Risk Management Measures

4.42 Given that the site is in Flood Zone 1, under NPPF guidance the proposed development is not required to incorporate flood mitigation measures.

4.43 Given that the site and all the surrounding access roads are located in Flood Zone 1, there is no requirement under the NPPF for an evacuation route.

4.44 It is also advised that the developer implement the following flood protection measures where appropriate:

- Solid, i.e. concrete, floors on all ground floor levels to provide protection against groundwater flooding, and;
- Raised electrical wiring and sockets, a minimum of 300mm above finished floor levels.
- Finished Flood Levels raised minimum 150mm above adjacent ground levels

Flood Warning Service

4.45 The EA operates a 24-hour telephone service on 0845 988 1188 that provides frequently updated flood warnings and associated floodplain information. Further information can be found on www.environment-agency.gov.uk/floodline. Floodline Warnings Direct is a free service operated by the EA that provides flood warnings direct to occupants by telephone, mobile phone, fax or pager.

- On receipt of a **FLOOD ALERT**, the property owners should:
 - Monitor the situation via local media;
 - Make themselves aware of forecast local weather conditions;
 - Alert others at the property of the situation;
 - Prepare to evacuate if necessary.
- On receipt of a **FLOOD WARNING**, the property owners should:
 - Follow advice to “go in, stay in, and tune in”;
 - Be prepared to follow instruction from the Emergency Services.
- On receipt of a **SEVERE FLOOD WARNING**, the property owners should:
 - Follow advice to “go in, stay in, and tune in”;
 - Remain attentive to local media forecasts and news bulletins;
 - Do not evacuate unless instructed to do so by the Emergency Services.

4.46 Upon receipt of a severe flood warning, the site should be evacuated. All site users should be advised not to attend the site until the site is deemed to be safe for return by the Emergency Services.

4.47 Site owners will be responsible for informing future site users of the risk posed by flooding. Further information can be found on www.environment-agency.gov.uk/floodline. Floodline Warnings Direct is a free service operated by the EA that provides flood warnings direct to occupants by telephone, mobile phone, fax or pager.

5. Site Geology & Existing Drainage Infrastructure

- 5.1 The British Geological Survey (BGS) Map indicates that the bedrock geology of the site is dominantly the London Clay Formation, comprising clay, silt and sand, except in the south-west corner of the site where the bedrock is the Lambeth Group, also composed of clays, silts and sands. However, a geotechnical survey performed by Listers in 2015 (*Appendix 2 – Site Geology*), which include trial pits and boreholes, shows that the Lambeth Group is more extensive on site than the BGS maps indicate, and that the Lambeth Group is present in approximately the entire southern half of the site, with the London Clay Formation in approximately the northern half of the site.
- 5.2 The BGS superficial geology map indicates that glacial Head deposits of clay, sand, silt and gravel are present throughout the site. This is confirmed by the geotechnical survey performed by Listers in 2015 (*Appendix 2 – Site Geology*).
- 5.3 Based on Listers report, *Soakaway Testing* section infiltration was conducted at the site within the Head strata. However, the testing did not follow the BRE365 standard and instead used a standpipe installation to estimate the infiltration rates. The infiltration results obtained are between 4.0×10^{-3} m/s and 6.6×10^{-3} m/s. See Listers report in *Appendix 2 – Site Geology*.
- 5.4 At the time of writing no BRE365 infiltration testing was conducted at the site and as such the rates discovered by Listers have not been used given the wide variability of the underlying soils. However, for the purposes of assessing various SuDS infiltration solutions for the site, a more conservative rate of 1×10^{-5} m/s was used in consideration of the potential variability, as described in the section above.
- 5.5 It is necessary to confirm the infiltration rates to BRE365 'Soakaway Testing' standard prior to the detailed design phase as well as undertake more detailed groundwater monitoring through the winter to identify if groundwater will affect any proposed infiltration SuDS. Once these are available, the proposed drainage strategy presented herein should be reviewed in the light of these findings.
- 5.6 Should infiltration prove to be unfeasible for the proposed site, it is recommended that runoff from the site be discharged into a local watercourse bounding the site to the south.

Local Watercourses

- 5.7 The Black Ditch Extension (an EA main river) runs parallel to southern side of Water Lane. This watercourse then becomes culverted approximately 50m south west of the site and flows west in the culvert for approximately 500m below Water Lane. There also appears to be ditch along the southern edge of the site. Local records show this is culverted below Water Lane (before the junction with Dapper's Lane) before tying into the Black Ditch Extension. Details of this culverted connection should be confirmed.
- 5.8 Should infiltration be deemed not feasible at the site, it is recommended to discharge surface water runoff from the proposed development to the existing ditch. Further assessment at the detailed design phase is required to establish the point of discharge and confirmation of discharge rates with the LLFA.
- 5.9 The site is currently developed with a residential dwelling, therefore it is assumed that sewer infrastructure is present. It is recommended that a CCTV survey be conducted prior to commencement of works to determine the type, layout and condition of the existing sewer infrastructure and its potential reuse in the new development.

6. SuDS Assessment

6.1 Paragraph 80 of the Planning Practice Guidance of the National Planning Policy Framework (NPPF) states that: generally, the aim should be to discharge surface run off as high up the following hierarchy of drainage options as reasonably practicable:

- into the ground (infiltration);
- to a surface water body;
- to a surface water sewer, highway drain, or another drainage system;
- to a combined sewer.

6.2 The SuDS management hierarchy is set out as follows:

SuDS Drainage Hierarchy			
		Suitability	Comment
	Infiltration	✓	Existing infiltration testing indicates good infiltration rates, however further testing to BRE365 needs to be conducted to validate the rates.
	Discharge to Surface Water Body	✓	Should infiltration prove unfeasible at the site, runoff should be conveyed to a local ditch at the southern site boundary.
	Discharge to Surface Water Sewer, Highway Drain or another Drainage System	x	Discharges to open watercourses take precedence over discharges to sewers under the NPPF.
	Discharge to Combined Sewer		

Table 4: SuDS Hierarchy

6.3 In accordance with the SuDS management train approach, the use of various SuDS measures to reduce and control surface water flows have been considered for the development based on the *West Sussex County Council SuDS Design Guide*:

"SuDS must be designed to ensure that development and occupants are protected from flooding, and that off-site flood risk is not increased. Where possible SuDS should aim to reduce the overall risk of flooding off-site and drain via infiltration ..."

The principal recommendations for sustainable drainage design of the *WSCC SuDS Design Guide* are:

1. Prevention - Good housekeeping and site design to reduce and manage runoff and pollution (e.g. land use planning, reduction of paved surfaces).
2. Source control - Runoff managed as close as possible to prevent migration of pollution (e.g. using green roofs, rainwater harvesting, permeable paving, filter strips).
3. Site control - Runoff managed in a network across a site using a series of SuDS features in sequence. By providing several SuDS in a series, treatment is enhanced. By slowing down water, sediment will settle out, and by passing water through a variety of features, different treatment mechanisms will be used (e.g. vegetation or gravel filtration).
4. Regional Control - Downstream management of runoff for a whole site/catchment (e.g. retention ponds, wetlands).

6.4 The suitability of SuDS components have been assessed as follows:

Suitability of SuDS Components		
SuDS Component	Description	Suitability
Infiltrating SuDS	Infiltration can contribute to reducing runoff rates and volumes while supporting baseflow and groundwater recharge processes. The suitability and infiltration rate depends on the permeability of the surrounding soils	✓
Permeable Pavement	Pervious surfaces can be used in combination with aggregate sub-base and/or geocellular/modular storage to attenuate and/or infiltrate runoff from surrounding surfaces and roofs. Liners can be used where ground conditions are not suitable for infiltration	✓
Green Roofs	Green Roofs provide areas of visual benefit, ecological value, enhanced building performance and the reduction of surface water runoff. They are generally more costly to install and maintain than conventional roofs but can provide many long-term benefits and reduce the on-site storage volumes	x
Rainwater Harvesting	Rainwater Harvesting is the collection of rainwater runoff for use. It can be collected from roofs or other impermeable area, stored, treated (where required) and then used as a supply of water for domestic, commercial and industrial properties	x
Swales	Swales are designed to convey, treat and attenuate surface water runoff and provide aesthetic and biodiversity benefits. They can replace conventional pipework as a means of conveying runoff, however space constraints of some sites can make it difficult incorporating them into the design	x
Rills and Channels	Rills and Channels keep runoff on the surface and convey runoff along the surface to downstream SuDS components. They can be incorporated into the design to provide a visually appealing method of conveyance, they also provide effectiveness in pre-treatment removal of silts	x
Bioretention Systems	Bioretention systems can reduce runoff rates and volumes and treat pollution through the use of engineer soils and vegetation. They are particularly effective in delivering interception, but can also be an attractive landscape feature whilst providing habitat and biodiversity	x
Retention Ponds and Wetlands	Ponds and Wetlands are features with a permanent pool of water that provide both attenuation and treatment of surface water runoff. They enhance treatment processes and have great amenity and biodiversity benefits. Often a flow control system at the outfall controls the rates of discharge for a range of water levels during storm events	x
Detention Basins	Detention Basins are landscaped depressions that are usually dry except during and immediately following storm events, and can be used as a recreational or other amenity facility. They are generally appropriate to manage high volumes of surface water from larger sites such as a neighbourhoods	x
Geocellular Systems	Attenuation storage tanks are used to create a below-ground void space for the temporary storage of surface water before infiltration, controlled release or use. The inherent flexibility in size and shape means they can be tailored to suit the specific characteristics and requirements of any site	✓
Proprietary Treatment Systems	Proprietary treatment systems are manufactured products that remove specific pollutants from surface water runoff. They are especially useful where site constraints preclude the use of other methods and can be useful in reducing the maintenance requirements of downstream SuDS	✓
Filter Drains and Filter Strips	Filter drains are shallow trenches filled with stone, gravel that create temporary subsurface storage for the attenuation, conveyance and filtration of surface water runoff. Filter strips are uniformly graded and gently sloping strips of grass or dense vegetation, designed to treat runoff from adjacent impermeable areas by promoting sedimentation, filtration and infiltration	x

Table 5 - Suitability of SuDS Components

- 6.5 Therefore, several SuDS components are deemed appropriate to be used in the following SuDS management train. It is suggested the use of **Permeable Pavement and Geocellular Systems** to manage surface water runoff from the proposed site. See *Appendix 4, Preliminary Surface Water Drainage Strategy*.

Permeable Paving

- 6.6 Permeable pavements are efficient in treating oils and metals but also in intercepting debris and silt. The Permeable Paving should be Type A (Full infiltration), the paving would be formed by the following layers:
- Permeable Concrete blocks.
 - Laying Course Material.
 - Geotextile filter.
 - Sub-Base: 6-20mm Clean Crushed Stone
 - Permeable membrane.
- 6.7 At the proposed site, permeable paving should be used on the trafficked routes. Solutions to provide attenuation storage within the permeable paving are possible in the sub-base layer. The sub-base aggregate should be of a minimum porosity of 30%. See *Appendix 4, Preliminary Surface Water Drainage Strategy*.

Geocellular

- 6.8 The Geocellular Systems are generally built by placing together (e.g. stacking) cuboid plastic structures with very high void ratios (min. 95%). The formed volume is then surrounded by a geotextile/membrane to form the attenuation tank. It is proposed to provide an attenuation tank – geocellular system at the rear of the proposed care home building. See *Appendix 4, Proposed Surface Water Drainage Strategy Layout*.
- 6.9 Should infiltration solutions be deemed unfeasible for the proposed development, throttle devices such as Orifice Plates must be set up in the proposed SuDS to control the flow rates, before being discharged or conveyed to the existing ditch at the south border.
- 6.10 Sediment Traps should be installed on the storm drainage pipework at incoming connections to SuDS features to reduce the incidence of blockage or silting up. External hard landscaping should be laid such that the arising runoff from the hardstanding areas can be collected and managed by the proposed SuDS train.
- 6.11 Guidance about proper use, installation and maintenance of any proprietary system should be provided by the supplier and incorporated into the site proposals at detailed design stage. Proper maintenance includes inspection and cleaning of collection systems, filters, throttles, valves and pumps.
- 6.12 SuDS components should be designed to accommodate and dispose of runoff from storms up to and including the 1:100 year + 40% climate change event without flooding.
- 6.13 The proposed SuDS devices herein adheres to the requirements set by NPPF and LLFA as it will manage the surface water volumes generated by the site, at a significantly reduced runoff rate during low-probability rainfall events. The proposals should therefore reduce the risks of surface water flooding at the site and surrounding properties.

7. Surface Water Drainage Strategy

- 7.1 In order to mitigate flood risk posed by the proposed development, adequate control measures are required to be considered. This will ensure that surface water runoff is dealt with at source and the flood risk on/off site is not increased over the lifetime of the development.
- 7.2 The existing site is partly comprised of impervious surfaces totalling approximately 1160m². These areas include the existing buildings and hardstanding. The proposed development will increase the impermeable footprint, therefore would result in an increase in runoff generated on site. The post development total impermeable area (excluding non-trafficked paving which should be designed as self-draining) will be approximately 3260m², according to the current plans.
- 7.3 Based on the West Sussex County Council SuDS Design Guide, it is required to control surface water runoff from new developments through the use of Sustainable Drainage Systems (SuDS). According to the NPPF, infiltration of runoff should take precedence over runoff discharges to watercourses and ultimately sewers. Should infiltration be deemed unfeasible, then off-site discharges of runoff to watercourse or sewers should be limited to, or as close as possible to the respective greenfield runoff rates.
- 7.4 The drainage strategy proposed herein focuses on the use of permeable paving within the trafficked areas to intercept, treat, attenuate and infiltrate runoff generated on the surface and adjacent hardstanding (ie paths). Runoff attenuated in the pavement's sub-base is ultimately discharged through infiltration into the sub-grade below, or, should infiltration not be feasible at the site, conveyed to downstream drainage components. The external hard standing areas should effectively be designed to self-draining.
- 7.5 The use of geocellular crate systems is proposed to manage runoff primarily from the proposed building. Runoff attenuated in the geocellular crates is ultimately discharged through infiltration into the sub-grade below, or, should infiltration not be feasible at the site, conveyed to downstream drainage components.
- 7.6 Should infiltration solutions at the site be deemed unfeasible, it is proposed to limit runoff flows off-site to the respective Greenfield rates, as per LLFA requirements. The runoff outflows could be controlled at the respective Greenfield rates by a complex flow control system using two orifice plates.
- 7.7 It is necessary to provide pre-screening to orifice plates to avoid blockages. The pre-screening mesh density (i.e. cell diameter) should be less than the diameter of the orifice plate it shields.
- 7.8 The design lifetime of a residential site is 100 years and an allowance for climate change should be considered in accordance with published guidance within the NPPF. The climate change criteria are reproduced below, and it is likely that the 'upper end' allowance for 2070 to 2115 is deemed suitable for the proposed development. To provide a worst case scenario, the 'upper end' 40% climate change allowance will be used (*Table 6*).

PEAK RAINFALL INTENSITY ALLOWANCE IN SMALL AND URBAN CATCHMENTS			
Applies across all of England	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Upper End	10%	20%	40%
Central	5%	10%	20%

Table 6 - Peak rainfall intensity allowance in small and urban catchments

- 7.9 The SuDS system proposed for the new development adheres to the Boroughs requirement of demonstrating surface water control and attenuation storage on site with the intention of mitigating the impact on the existing flooding regime.

Runoff rates

- 7.10 According to the plans provided by the client, the total impermeable area of the site is associated with a Greenfield Runoff Rate (Q_{BAR}) of 1.3l/s or 4.2l/s during a 1 in 100 year flood event. Other results properly factored for each return period and area of the site are shown in *Appendix 3, Calculations* and also in *Table 7 – Surface Water Discharge Rates Summary* below.
- 7.11 Should infiltration SuDS solutions not be feasible at the proposed site, following the guidance of the West Sussex County Council (WSCC) SuDS Design Guide it is recommended to control flows post-development at the respective Greenfield runoff rates. To be referred to only if a detailed assessment of runoff discharges by infiltration concludes that infiltration solutions are unfeasible for the proposed site.

SURFACE WATER DISCHARGE RATES SUMMARY					
	Area (ha)	Discharge Rates (l/s)			
		Q_{BAR}	1 year	30 year	100 year
Greenfield	0.326	1.2	1.0	2.6	3.7
Existing	0.116	-	15.7	30.8	30.9
Proposed (+40% CC)	0.326	-	1.0	2.6	3.7

Table 7 – Surface Water Discharge Rates Summary

Attenuation Storage

- 7.12 Attenuation storage is needed to temporarily store water during periods when the runoff rates from the development site exceed the allowable discharge rates from the site.
- 7.13 Rainfall depths for the 1 in 100 years Return Period plus 40% of climate change were produced using the *Microdrainage* software in order to estimate the largest volume, *critical storm*, for typical storm durations up to and including 48 hours for the proposed site, with discharges at an infiltration rate of 1×10^{-5} m/s. See calculations in *Appendix 3, Calculations*.
- 7.14 Thus, it meets with the standards required by the WSCC SuDS Design standards for the sustainable drainage system to mitigate against the current regime and avoid the flood risk within the development in a 1 in 100 year rainfall event with an allowance for climate change.

On Site Drainage and Storage Systems

- 7.15 Preliminary calculations indicate that during the 1:100 year +40% climate change rainfall event scenario, approximately 47m³ of storage will be required in the road permeable paving and 118m³ in the proposed geocellular crate system.
- 7.16 It is proposed to provide permeable paving in all external paved areas to intercept, treat, attenuate and infiltrate runoff generated on its surface. It has been assumed at this stage that a minimum storage depth of 110mm deep sub-base of 6-20mm clean crushed stone with 30% minimum porosity should be provided, this would offer upwards of 49.7m³ (to be confirmed by CBR tests). An infiltration rate of 1×10^{-5} m/s was assumed at the base of the SuDS component.

- 7.17 It is recommended to provide a geocellular system at the rear of the proposed care home building to manage runoff generated by the building. The plans included in appendix 4 show a geocellular system with a surface area of 170m² by 800mm deep crates with 95% minimum porosity providing upwards of 129m³. An infiltration rate of 1x10⁻⁵ m/s was assumed at the base of the SuDS component. See *Appendix 4, Preliminary Surface Water Drainage Strategy Layout*.
- 7.18 Should infiltration not be feasible at the site, outflows from the proposed drainage scheme should be to the ditch, with flows controlled at Greenfield runoff rates.

Design Exceedance

- 7.19 In the event of drainage system failure under extreme rainfall events or blockage, flooding may occur within the site. In the event of the development's drainage system failure, the runoff flow will be dictated by topography on site. Design of external ground levels will need to be undertaken at detailed design stage to finalise these routes, but some indicative flow paths have been indicated on the outline strategy drawings. See *Appendix 4, Proposed Surface Water Drainage Strategy*.
- 7.20 The indicated finished floor level of the proposed building is 150mm above surrounding finished ground mitigating against any potential surface water flows entering/damaging the building.

Water Quality

- 7.21 Adequate treatment must be delivered to the water runoff to remove pollutants through SuDS devices, which are able to provide pollution mitigation. Pollution Hazards and the SuDS Mitigation have been indexed in the specialized literature CIRIA 753 'The SUDS Manual'. This is determined by the following restriction:

$$\text{Total SuDS Mitigation Index} \geq \text{Pollution Hazard Index}$$

- 7.22 The Pollution Hazard Indices are summarized in *Table 8 – Summary of Pollution Hazard Indices for different Land Use* below:

POLLUTION HAZARD INDICES FOR DIFFERENT LAND USE CLASSIFICATIONS				
LAND USE	Pollution Hazard Level	Total suspended Solids (TSS)	Metals	Hydrocarbons
Residential Roofs	Very Low	0.2	0.2	0.05
Individual property driveways, residential car parks, low traffic roads	Low	0.5	0.4	0.4

Table 8 – Summary of Pollution Hazard Indices for different Land Use

- 7.23 The Mitigation Indices of the proposed SuDS techniques are summarized in the *Table 9 - Indicative SuDS Mitigation Indices* below. It can be seen the water treatment provided by this SuDS train is enough to remove the pollutants.

INDICATIVE SuDS MITIGATION INDICES FOR DISCHARGES TO SURFACE WATER			
SuDS Component	Total suspended Solids (TSS)	Metals	Hydrocarbons
Permeable Pavement	0.7	0.6	0.7
Proprietary Treatment Systems	Details should be provided at the detailed design phase to account for the final SuDS strategy layout and wider construction design details.		

Table 9 – Indicative SuDS Mitigation Indices

Adoption and Maintenance

7.24 All onsite SuDS and drainage systems will be privately maintained. A long term maintenance regime should be agreed with the site owners before adoption. In addition to a long term maintenance regime, it is recommended that all drainage elements implemented on site should be inspected following the first rainfall event post construction and monthly for the first quarter following construction.

Proposed Schedule of Maintenance				
Item	Visual Inspection	Cleanse / De-sludge	CCTV Survey	Comments
Surface Water Drainage System (pipework, chambers etc.)	5 years	10 years	10 years	Cleansing to be carried as necessary
Gullies/Channels	1 year	1 year	N/A	Cleansing to be carried as necessary
Permeable Block Paving	1 year	'Swept' clean of debris every 2 years.	N/A	Lift blocks and remove sand bedding and replace and re-bed paving – refer to individual manufacturers recommendations.
Geocellular Tanks	Yearly	As required	5 years	Remove sediment from pre-treatment structures; Inspect inside of tank for sediment build-up and remove as necessary

Table 10 - Proposed Schedule of Maintenance for Below Ground Drainage

Foul Water Drainage

7.25 It is proposed to formalise the foul water drainage from the site into the Southern Water Foul Water manhole located in Water Lane (manhole reference 2501). Initial calculations show a new gravity connection would be feasible, however to ensure the additional foul water flows that would be generated from the development do not increase pressure on the local network, a Pre-Development Enquiry has been submitted to check if capacity is available. Southern Water have confirmed that capacity is available within the sewer to accommodate the proposed foul water flows (see Pre-development Enquiry in Appendix 1).

7.26 A new connection will need to be constructed from the site in order to connect the proposals to the sewer at manhole ref 2501. This connection will need to be adopted and designed in accordance with Sewers for Adoption 7th Edition.

8. Conclusions

- 8.1 This study has been undertaken in accordance with the principles set out in NPPF. We can conclude that, providing the development adheres to the conditions advised in this report, the proposals can be implemented without increasing flood risk within the locality in accordance with objectives set by Central Government and the EA.
- 8.2 The site is located within Flood Zone 1, and at low risk of flooding from rivers and seas, low risk of pluvial flooding, at moderate risk of groundwater flooding (at the low parts of the site bordering Water Lane), and at low risk of sewer flooding. The risk of groundwater flooding needs to be further assessed through further groundwater monitoring. However, should groundwater flooding occur, this would happen at the topographically low areas of the site (along Water Lane) and would not put the proposed building at risk of flooding, as result it is considered that overall flood risk to the site is low.
- 8.3 The total area of the site is approximately 7200m² (0.72 ha). Existing impermeable areas are associated with the existing structures and other hardstanding areas, with a total area of approximately 1160m² (0.116 ha). The proposed development will increase the total impermeable site area to approximately 3260m² (0.326 ha).
- 8.4 Two SuDS elements are proposed to manage runoff from the site post-development. Permeable paving is recommended to manage runoff from the driveways, parking and bounding paths. Geocellular crate system are proposed to manage runoff from the care home building.
- 8.5 Based on Listers report, there is a potential for both contamination and infiltration on site. As such further testing is needed to insure any infiltration SuDS are not placed in areas at risk of contamination and in areas best suited to optimise the permeability of the underlying soils. The Listers report states that infiltration results, undertaken in borehole obtained are rates between 4.0x10⁻³ m/s and 6.6x10⁻³ m/s. These rates are very good and indicate infiltration should be feasible. However, it is recommended further infiltration (and contamination) testing is done to BRE365 infiltration testing in combination with winter groundwater monitoring to confirm the suitability of infiltration on site. For the purposes of assessing various SuDS infiltration solutions for the site, a conservative rate of 1x10⁻⁵ m/s was used in the calculations.
- 8.6 It is necessary to confirm the infiltration rates to BRE365 'Soakaway Testing' standard prior to the detailed design phase and the proposed drainage strategy presented herein reassessed thereafter. Should infiltration prove to be unfeasible for the proposed site, it is recommended that runoff form the site be discharged into a local watercourse bounding the site to the south. The discharge rates into the ditch should not exceed greenfield runoff rates, if feasible.
- 8.7 In the event of drainage system failure under extreme rainfall events or blockage, flooding may occur within the site. In the event of drainage system failure, overland flow will be dictated by the existing levels, with flows directed south towards the ditch and the nearby water course. Ground levels around building should be designed to direct flows away from building thresholds towards the south where possible.
- 8.8 Due to the low level of pollution indices of the roof and driveway area, permeable pavement systems are considered effective to remove these pollutants.

- 8.9 All onsite SuDS and drainage systems will be privately maintained. A long term maintenance regime should be implemented the site owners as outlined in this report. In addition to a long term maintenance regime, it is recommended that all drainage elements implemented on site should be inspected following the first rainfall event post construction and monthly for the first quarter following construction.
- 8.10 Foul water flows from the proposals are shown to discharge into the publick
- 8.11 This study has been undertaken in accordance with the principles set out in NPPF. We can conclude that providing the development adheres to the conditions advised in the conclusions of this report, the said development proposals can be accommodated without increasing flood risk within the locality in accordance with objectives set by Central Government and the EA.

The findings and recommendations of this report are for the use of the client who commissioned the assessment, and no responsibility or liability can be accepted for the use of the report or its findings by any other person or for any other purpose.

Appendix 1 – Supporting Information

- *Proposed Development Drawings*
- *Topographic Survey*
- *Pre-Development Enquiry*

Stavros
Ambiental Environmental Assessment
Ambiental Technical Solutions
The Sussex Innovation Centre
Science Park Square
Falmer, Brighton
BN1 9SB

Developer Services
Southern Water
Sparrowgrove House
Sparrowgrove
Otterbourne
Hampshire
SO21 2SW

Tel: **0330 303 0119**

Email: developerservices@southernwater.co.uk

Your Ref:

Our Ref:
DS_CC_PDE-101816

Date:
06 June 2018

Site: Land off Dappers Lane, Angmering, Littlehampton, West Sussex, BN16 4EN.

Dear Stavros,

I am now in receipt of the results of the capacity check you requested for the above development site.

FOUL WATER

Following initial investigations, there is currently adequate capacity in the local sewerage network to accommodate a foul flow for the above development at/downstream of manhole reference TQ07042501. Please note that no surface water flows (existing or proposed) can be accommodated within the existing foul sewerage system.

It should be noted as from the 1st April 2018 we are moving to the "New Connections Services Charging Arrangements". We understand that moving to new arrangements presents uncertainty for customers, particularly where they may have already committed to a development based on previous charging arrangements. We have worked with our stakeholders and Water UK to agree a set of principles by which we will base our charges. Please read through our new charging arrangement documents which are now available to read via the following link:

<https://beta.southernwater.co.uk/infrastructure-charges>

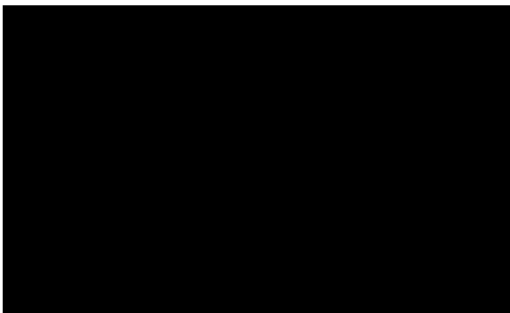
Alternatively, new appointees and variations (NAVs), also known as 'inset' companies, can provide new connection services or take ownership of the new water and wastewater

connection infrastructure provided for a new development. NAVs are appointed by Ofwat and replace the regional water company. It is for the developer to choose whether to use a NAV or the regional water company to supply services for new sites, according to certain legal criteria.

It should be noted that this information is only a hydraulic assessment of the existing sewerage network and does not grant approval for a connection to the public sewerage system. A formal S106 connection application is required to be completed and approved by Southern Water Services. Please see the following link:

[https://developerservices.southernwater.co.uk/ConnectiontoPublicSewer/Application Form](https://developerservices.southernwater.co.uk/ConnectiontoPublicSewer/ApplicationForm)

Should you require any further information, please contact us at the above mentioned phone number or address.



grant approval for any designs/drawings submitted for the capacity analysis. The
months from the date of issue of this letter.

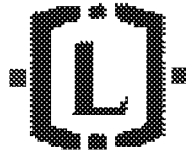
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Appendix 2 – Site Geology

- *Soil Investigation Report*

LISTERS

Geotechnical Consultants



Frontier Estates Limited

Ground Investigation

**Dappers Lane
Angmering
West Sussex
BN164DA**

**Report No: 14.11.004
January 2015**

MAIN OFFICE & LABORATORIES

DOCUMENT RECORD

Report Title Ground Investigation Report

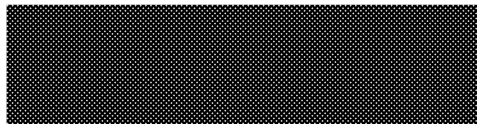
Project Title New Care Home Development

Project Address Land off Dappers Lane, Angmering, West Sussex BN16 4DA

Project Number 14.11.004

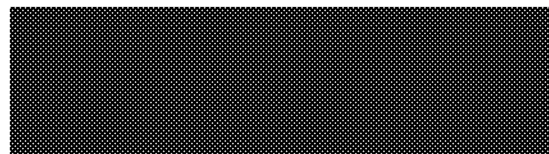
Client Frontier Estates Limited

Prepared By:



Signed.....
Ian Evetts
Director
MSc, HNC, FGS

Checked By:



Signed.....
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Director
B.Sc (Hons), M.Sc, DIC, FGS, C.Geol

For and on behalf of Listers Geotechnical Consultants

Issue No	Date	Status
1	27 th January 2015	Draft
2	22 nd October 2015	Final

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EXECUTIVE SUMMARY

Project Reference	14.11.004
Site Location	Land adjoining Dappers Lane, Angmering, West Sussex BN16 4DA.
OS Grid Reference	507340, 104711.
Development Proposals	A new two storey main care home building along with several self contained, up to two storey apartment and bungalow buildings.
Existing Buildings	Two storey house with associated out buildings and a domestic garage (Broadlees).
Topography	Site slopes down some 7m from the northern boundary to Water Lane at the southern boundary.
Vegetation	An overgrown area with dense shrubs and mature trees was present in the southern part of the site. Much of the overgrown vegetation had been removed prior to our site visit. Mature trees and dense vegetation remained however along the sites boundaries and within landscaped areas, along with occasional trees in the paddock.
Published Geology	Superficial Head deposits underlain by Lambeth Group deposits across the site with the exception of the extreme south western corner, where the underlying Tarrant Chalk member is shown sub cropping beneath the Head deposits. The London Clay Formation, which overlies the Lambeth Group is shown immediately to the north west of the site.
Site History	Open ground until circa 1942 when a small gravel pit is shown on the site. Broadlees recorded circa 1957 along with out-buildings and a glass house. Post 1970 gravel pit no longer recorded and house extended sometime after 1994 and the glass house is no longer shown on the 2010 map.
Hydrology	The nearest surface watercourse is an unnamed tertiary river 32m south of the site that flows towards the south west. A pond is also recorded 15m to the south east of the site.
Hydrogeology	Secondary (undifferentiated) Aquifer, associated with the superficial deposits. Secondary A Aquifer and Principal Aquifer associated with the Lambeth Group and Tarrant Chalk Member bedrock deposits respectively.
Geotechnical Hazards	A Gravel Pit is recorded on the site based on the historical maps. There is a moderate recorded risk of the occurrence of shrinking and swelling clay identified for this site.
Ground Conditions Encountered	Topsoil/Made Ground overlying suspected Head deposits, which in turn directly overlie the London Clay Formation in the northern part of the site and the Lambeth Group in the southern and eastern parts of the site.
Groundwater Encountered	Ground water seepages/inflows were encountered within the Head deposits and the granular Lambeth Group deposits at depths of between 0.9m to 5.5m. Entries were also recorded within the London Clay Formation at depths of 6.5m and 7.5m below the existing ground level.
Ground Contamination	Elevated lead, BaP, benzo(b)fluoranthene and dibenzo(a,h)anthracene were encountered at concentrations above corresponding guideline screening values.
Groundwater Contamination	Low risk to groundwater receptors.
Site Remediation Required	Removal of contaminated soils or incorporation of a cover layer system in proposed gardens and landscaped areas.

Soil Gases	Characteristic Situation CS2 in accordance with BS8485:2007 and traffic light colour 'Amber 1' in accordance with NHBC Report No 10627 for residential properties. The BGS advises that basic radon gas protection measures are necessary.
Foundations	Natural soils may be capable of supporting the buildings on strip/trench fill foundations at not less than 1m below existing ground level or 0.20m into the top of the natural formation, whichever is the deeper. Should the allowable bearing pressure prove insufficient or problems with dewatering prove difficult, foundations could be supported on piles founded within the underlying Head, London Clay, Lambeth Group and possibly the underlying Tarrant Chalk Member.
Allowable Bearing Pressure	An allowable bearing capacity of 120kPa may be adopted for foundations not exceeding 1.0m in width.
Floor Slabs	Provided all the Topsoil and Made Ground is stripped off, ground bearing floor slabs could be constructed placed on a layer of well compacted granular fill. Where it is required to deepen the main foundations below 1.50m depth, due to the presence of trees and large shrubs (existing or in areas of recent vegetation) or where seasonal desiccation is occurring then ground floor slabs will require suspending in accord with NHBC guidelines.
Waste Soil Classification	Made Ground soil on this site is classified as non-hazardous due to elevated TOC. A higher TOC limit value may be permitted by the Environment Agency however at some inert waste landfill sites. Natural soils at the site are considered to be uncontaminated and may be disposed of as inert waste. Subject to approval from the receiving landfill.
Soakaways	Due to the variability of the soils encountered infiltration testing in machine dug trial pits is recommended to assess the feasibility of soakaways. Consideration will be required however to shallow ground water entries and to avoid promoting slope instability should such a solution be sought.
Roads & Hard Standing Design	A subgrade CBR value of 2% is adopted for design purposes founded in the Head deposits. Formation soils should be considered to be frost susceptible, requiring a minimum pavement construction thickness of 450mm.
Chemical Attack On Buried Concrete	Design Sulphate Class DS -1 ACEC Class AC-1 for buried concrete in the Made Ground, Head and Lambeth Group. DS -2 ACEC Class AC-1s for concrete extending into the London Clay Formation.

This executive summary should be read in conjunction with the main report.

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APPENDICES

APPENDIX A - PLANS, PLOTS AND PHOTOGRAPHS

- Site Location Plan
- Exploratory Hole Location Plan - Existing Site Layout
- Exploratory Hole Location Plan – Showing Development Proposals
- Proposed Sections Showing Existing and Proposed Site Levels
- Plan Showing the Development Proposals & Indicative Areas Requiring Remediation
- Site Photographs
- SPT v Depth Plot
- Pile Design Data

APPENDIX B – FIELDWORK AND TESTING

- Trial Pit Logs
- Cable Percussive Borehole Logs
- Standard Penetration Test Table
- Hand Auger Borehole Logs
- Gas Monitoring

APPENDIX C- LABORATORY TESTING RESULTS AND TABLES

- Geotechnical Laboratory Testing Results
- Plasticity Chart
- Moisture Content v Depth
- Laboratory Shear Strength Results (Hand Vane and Pocket Penetrometer)
- Chemical Analysis Testing Results
- HazWasteOnline Summary
- WAC Testing Results

APPENDIX D - DESK STUDY INFORMATION

- GroundSure EnviroInsight
- GroundSure GeoInsight
- Ordnance Survey and National Grid Maps

GROUND INVESTIGATION REPORT

INTRODUCTION

A ground investigation has been undertaken for proposed new care home development on land adjoining Dappers Lane, Angmering, West Sussex BN16 4DA. A Site Location Plan is provided in Appendix A.

The Ordnance Survey National Grid reference for the centre of the site is 507340, 104711.

This report describes the work carried out by Listers Geotechnical Consultants, the ground conditions encountered and discusses their implications with regard to the proposed development.

This report describes the desk study and intrusive site investigation activities carried out by Listers Geotechnical Consultants in order to provide an evaluation of the ground conditions and the extent of any soil contamination present on the site. The report presents initial human health and groundwater risk assessments based on the findings of the desk study information and subsequent contamination laboratory testing. The contamination risk assessment has been carried out using the source-pathway-receptor risk assessment methodology.

The report also discusses the geotechnical implications with regard to the proposed development based on the findings of the fieldwork and subsequent laboratory testing.

Verbal instruction to undertake the investigation were received from Gelder & Kitchen LLP on 6th November 2014, acting on behalf of the client, Frontier Estates Limited.

This report has been prepared for the sole use of the client and their professional advisors. This report shall not be relied upon by third parties without the express written authority of Listers Geotechnical Consultants. If an unauthorised third party comes into possession of this report they must not rely on it and the authors owe them no duty of care and skill.

SCOPE OF THE INVESTIGATION

The scope of the investigation was to undertake a desk study and walkover survey, provide an assessment of the geotechnical engineering properties of the ground and the extent of any soil contamination on the site. A contaminated land risk assessment was undertaken based on the Contaminated Land Exposure Assessment (CLEA) and Environment Agency RTM guidelines.

The investigation also includes a preliminary assessment of the feasibility of adopting a soakaway drainage solution at the site, as well as providing parameters to aid pavement design.

PROPOSALS

It is understood the development proposals have not been finalised however it is proposed to redevelop the site to accommodate a new two storey main care home building along with several self contained, up to two storey apartment and bungalow buildings with associated gardens, landscaped areas, access roads and car parking.

The contaminated land risk assessment has been prepared in support of the planning application for the development.

SITE INFORMATION AND WALKOVER SURVEY

A walkover survey of the site and its immediate surrounds was undertaken on the 14th November 2014. A selection of site photographs is presented in Appendix A along with the site plans.

The site lies in a predominantly residential area, and is currently occupied by a single two storey house with associated out buildings and a domestic garage (Broadlees). The remnants of a former structure is present adjacent to the out buildings, which is suspected to have been a former glass house. The house was accessed via a gravel drive off Dappers Lane which forms the western boundary to the site. A paddock with sheep was present within the eastern part of the site with further open fields beyond. Areas of concrete hardstanding were present in the north western corner of the paddock and an old oil drum, possibly used for burning garden waste, was present on one of the concrete slabs. An overgrown area with dense shrubs and mature trees was present in the southern part of the site, which was south of the gardens to the main house. A septic tank was present within the overgrown area along with a localised depression in the ground surface which led to Dappers Lane. The localised depression was estimated to be in the order of 1.5m to 2m lower than the surrounding site topography. Water Lane formed the southern boundary to the site and a small light industrial estate north of the site.

The site occupied an area of approximately 1.27 hectares and slopes down some 7m from the northern boundary to Water Lane at the southern boundary.

Much of the overgrown vegetation has been removed prior to our site visit to enable a topographical survey to be conducted and to aid access for our investigation plant however matures trees and dense vegetation remained in some areas. Further trees and vegetation was present along the sites boundaries and in landscaped areas along with occasional trees within the paddock.

A suspected drainage ditch was present in some places along the southern boundary and beyond Water Lane, a pond was noted a short distance south of the site.

GEOLOGY

Published Geology

Reference to the British Geological Survey 1:50,000 scale map and other published geological information on the area indicate that the site is underlain by superficial Head deposits of the Quaternary age. The Head deposits are underlain by Lambeth Group deposits across the site with the exception of the extreme south western corner, where the underlying Tarrant Chalk member is shown sub cropping beneath the Head deposits. The London Clay Formation, which overlies the Lambeth Group, is shown immediately to the north west of the site.

Head deposits are generally poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hillwash and soil creep. Head typically comprises sand and gravel, locally with lenses of silt, clay or peat and organic material.

The London Clay Formation is generally represented by a blue grey or grey brown silty to very silty clay, clayey silt and sometimes silts, with some layers of sandy clay. It also includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation. Generally the London Clay Formation occurs to in excess of 30m in thickness however it is likely to be much thinner in this area as the underlying Lambeth Group is shown sub cropping at the site.

The Lambeth Group is typically represented by mottled, variable sequences mainly of clay, sometimes silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerates. The Lambeth Group can occur to thicknesses in the order of 28m in the area however is likely to be significantly reduced in thickness at the site and is possibly absent towards the south western corner, where the underlying Tarrant Chalk Member is shown.

The underlying Tarrant Chalk Member typically comprises white chalk with flints and forms part of the Upper Chalk which extends to in excess of 100m thickness.

SOLUTION FEATURES

Chalk, as a calcium-carbonate rich rock, is highly susceptible to dissolution by water containing carbon dioxide. This dissolution can create three common types of features within the chalk, grouped together under the generic term 'dissolution features'. These features include:

- **Sinkholes:** Depressions at the ground surface caused by the collapse of overlying chalk or superficial deposits into underground voids created by dissolution. Shape and size dependent on underlying void feature.

- **Solution pipes:** A feature in the surface of the Chalk caused by increased dissolution in an area of closely spaced discontinuities. These features may, or may not, have a ground surface expression. Up to 20 metres diameter through commonly much smaller.
- **Swallow Holes:** A void within the surface of the Chalk where a stream is ‘swallowed’ by the Chalk to flow underground. Often occur at the junction of impermeable strata and Chalk. Infilled ancient swallow holes do exist where streams used to flow and may not have any surface expression. Up to 14m in diameter, through commonly a few metres.

HISTORIC BOREHOLES

The records of two historic boreholes have been obtained from the British Geological Survey.

The nearest borehole to the site is located approximately 220m to the north west at Lansdowne Nursery. The borehole records 1.5m of Head deposits overlying 5.8m of gravel and flints, which possibly represents superficial River Terrace deposits. The combined London Clay (London Clay Formation) and Reading Beds (Lambeth Group) is recorded extending to 53m depth and Upper Chalk continues below and was proven to 62.5m depth.

The second borehole is located some 500m to the north west and records gravel and clay drift deposits to 7m underlain by London Clay to 18m depth and the Reading Beds to 45m. The Chalk deposits extend below this depth and continued to the base of the borehole at 69m depth.

DESK STUDY AND BACKGROUND INFORMATION

GENERAL

A desk study review of the site and its history has been undertaken to establish the former land usage and the potential for any historically derived sources of chemical contamination. A copy of the desk study information is presented in Appendix D of this report.

It should be noted that the information provided in the desk study is obtained from independent third party sources. It is provided in good faith, but no guarantee can be provided as to its accuracy. The Client should make independent enquiries on information provided in the desk study information that may impact on the proposed development. The desk study information is not necessarily exhaustive and further information relevant to the site may be available from other sources.

The desk study comprises a review of the following consultations and information sources:

- Environment Agency (EA)
- Natural England
- National Geoscience Information Service
- Health Protection Agency
- Centre for Ecology & Hydrology
- British Geological Survey (BGS)
- Contemporary Trade Directories
- Historical Ordnance Survey maps

Information from the above referenced sources has been utilised to develop a conceptual model of the site for use in the geotechnical appraisal and source-pathway-receptor risk assessment.



HISTORY OF THE SITE

The history of the site has been established by reviewing the historical Ordnance Survey maps of the area, collected as part of the desk study information. This has established the following:

Time Period	Historical usage of the site	Historical usage of the surrounding Area
1876-1877	The site is part of an open field and is bound by Dappers Lane to the west and Water Lane to the south.	Further open fields are shown to the north and east of the site. Two ponds are shown some 15m south east of the site beyond Water Lane. The ponds appear to be supplied by a watercourse which flows approximately from the north east to the south west with Avenals Farm beyond. Angmering is present some 100m to the south west.
1897-1899	No obvious changes have occurred on the site.	One of the ponds is now indicated as marsh land. A Gravel Pit is recorded 220m to the south west and an Old Chalk Pit 870m to the south east.
1909-1932	No obvious changes have occurred on the site.	The gravel pit to the south west is no longer shown. A small pond is indicated 30m west of the site.
1942-1943	A small Gravel Pit is shown midway along the western site boundary with an access track off Dappers Lane.	Further marsh land is shown south of the site adjacent to the remaining pond. Angmering has been significantly extended northwards and Lansdowne Nursery, comprising glass houses and a water tower are recorded 110m to the north west.
1957	Buildings are now shown in the north western part of the site, one of which is consistent with the existing out buildings. A glass house is also shown adjacent to the out buildings the remnants of which are still visible today. Several small buildings are also shown in the north western corner of the existing paddock. A building is located at the approximate location of the existing house but is smaller in size and is recorded as Broadlees.	St Deny's Nursery is recorded immediately north of the site and comprises various glass houses and buildings along with a tank which is located approximately 30m north of the site boundary. Sloping ground is now shown beyond the pond and watercourse south of the site and the marsh land is no longer recorded. A Builder's Yard is shown 10m south west of the site and houses are shown to the west of Dappers Lane.
1970-2014	The Gravel Pit is no longer recorded. Limited detail is shown on the large scale maps post 1994 however the glass house is no longer shown on the 2010 map. It is considered that Broadlees main house has been extended to its current layout at some point during this period.	Lansdowne Nursery is no longer recorded and is replaced by two small semi detached houses. Angmering continues to expand west of the site, replacing the small pond shown on earlier maps.

We understand from the site owner that the site was formerly occupied by a nursery with a green house. We understand the glass from the former greenhouse was buried in an excavation within the southern part of the existing paddock area. We understand the excavation is estimated to have been approximately 15 feet by 15 feet (4.6m by 4.6m) and approximately 12-15 feet deep (3.7 to 4.6m). Topsoil was subsequently introduced to the existing landscaped gardens and paddock area.

HYDROLOGY

The nearest surface watercourse and unnamed tertiary river 32m south of the site that flows towards the south west. In this area the watercourse has not been designated with a River Quality by the Environment Agency. A surface water feature is also recorded 15m to the south east of the site which corresponds to the pond, south of Water Lane.

It should be appreciated that the site is recorded to be within a Zone 2 Fluvial floodplain, which possibly resulted in the designation 'Water Lane', which forms the southern boundary to the site. It should be noted that this information does not constitute a site specific Flood Risk Assessment, which may be required for the development to support a planning application or satisfy planning conditions.

There are no recorded current surface water abstraction licenses located within 1000m of the site.

HYDROGEOLOGY

Information obtained from the Environment Agency indicates that the site is located on a Secondary (undifferentiated) Aquifer, associated with the superficial deposits. This probably corresponds to the Head deposits recorded at the site. The site is also recorded to be located on both a Secondary A Aquifer and Principal Aquifer associated with the Lambeth Group and Tarrant Chalk Member bedrock deposits respectively.

The aquifer designation data is based on geological mapping provided by the British Geological Survey. The maps are divided into two different types of aquifer designation:

- **Superficial (Drift)** - permeable unconsolidated (loose) deposits. For example, sands and gravels.
- **Bedrock** - solid permeable formations e.g. sandstone, chalk and limestone.

For each type there are Principal, Secondary A, Secondary B and Unproductive Strata, each with a decreasing rank of importance.

There is one current groundwater abstraction licenses located within 1000m of the site. This is located 818m to the south for horticultural watering.

The site is not within 1500m of a potable water supply and according to information provided by the Environment Agency the site is outside of any Source Protection Zones (SPZ). An SPZ is a protection zone placed around a well or borehole that supplies groundwater of potable quality.

There have been four substantiated pollution incident to controlled waters within 250m of the site. The nearest was recorded 37m south east of the site and is described as a significant impact to freshwater water course in 1999. The remaining three incidents were all located 165m to the north of the site and is recorded as diesel: petrol having a minor Category 3 impact to water and land. In view of the anticipated hydraulic gradient at the site and nature of the pollution, it is considered unlikely that these incidents would have significantly affected the site itself.

LANDFILL, WASTE TREATMENT AND INDUSTRIAL USAGE SITES

Reference to records from the BGS, the Environment Agency and the Local Authority indicates that there are three Environment Agency ELV (End of Life Vehicle) facilities located some 900m to the north west of the site, there are no further waste transfer sites, waste treatment sites or waste management facilities within 1000m of the site area. It is considered unlikely that any of these facilities would affect the site area.

Reference to records also indicates that there are no recorded current/historical landfill disposal sites within 1000m of the site.

There have been no applications for Integrated Pollution Control Licenses or Integrated Pollution Prevention and Control (IPPC) licenses within 500m of the site.

There are nine trade directory/potentially contaminative industrial site entries that have been found within 250m of the site, these are all listed in Appendix D. The nearest includes industrial work wear production 26m to the west and a cleaning equipment and supplies business 60m to the north.

There are no recorded active fuel filling stations within 500m of the site.

WORKED OUT GROUND/MADE GROUND

A Gravel Pit is recorded on the site based on the historical maps and ponds between 12m and 16m to the south east. Unspecified workings are recorded 39m south east of the site based on the 1974 maps, which probably corresponds to slopes recorded in the area. A Gravel Pit is recorded 218m to the south west based on the 1896 maps and this is also recorded as a ceased Angmering Gravel Pit by the British Geological Survey along with a chalk pit 867m to the south east.

RADON GAS

Groundsure utilise information from the Health Protection Agency (HPA) to determine if the site is within a radon affected area and the British Geological Survey (BGS) database to determine if radon protection is considered necessary. The BGS data complies with the BR 211, 'Radon: guidance on protective measures for new dwellings' and indicates that basic radon gas protection is required for new dwellings or extensions.

RISK OF GASEOUS CONTAMINATION

We have provisionally assessed the risk of ground gas impacting the site, by reference to guidance given in the paper "A pragmatic approach to ground gas risk assessment for the 21st Century" Card and Wilson, 2011. This is a follow up paper to the CIRIA Report 665 and is compatible with that document.

- No credible sources or pathways for landfill gas migration from an off site landfill have been identified.
- The site has not been a registered landfill.
- The Made Ground is not expected to be 5m deep or an average of 3m in thickness.
- The site is located on a carbonate rich rock that can produce carbon dioxide.
- Radon protection measures are required for this site.
- Table 2 in the Card and Wilson 2011 paper has been referenced and the site does not lie on a potential naturally organic soil or a humic or degradable Made Ground soil, as defined in this table.

The site is recorded to be located on carbonate chalk deposits in the extreme south western corner of the site. Such deposits do not typically produce methane and although such deposits can produce carbon dioxide, the generation is not considered likely to be sufficiently high to present a significant risk to end users. Although the site is not recorded to be within close proximity of a landfill site a former gravel pit occupied the site. The topography suggests that this has not subsequently been infilled. We have however installed groundwater monitoring standpipes at the site and as a precaution these have been monitored for ground gasses twice over a period of one month. The results are reported later in this report.

GROUND RELATED HAZARDS

The desk study information identified that the site lies within an area where small scale chalk mining may occur but is likely to be restricted in extent.

There is a moderate recorded risk of the occurrence of shrinking and swelling clay identified for this site.

The risk of subsidence from landslides, dissolution of soluble rocks, compressible deposits, collapsible deposits and running sand is also recorded to be low, very low or negligible.

BACKGROUND SOIL CHEMISTRY

Information from the BGS regarding background levels of some heavy metals in the natural soils estimates that in the site area, rural soil has the following levels of arsenic, cadmium, chromium, lead and nickel:

Contaminant	Level in rural soil (mg/kg)
Arsenic	15
Cadmium	<1.8
Chromium	60-90
Lead	<150
Nickel	15-30

These concentrations are all well below the generic environmental screening standards for a residential site.

POTENTIALLY SENSITIVE LAND USES

The site is not located in close proximity to any environmentally sensitive land uses, however the area is located within a nitrate vulnerable zone. The nearest environmentally sensitive site is located 358m to the east at the South Downs Site of Special Scientific Interest (SSSI) site.

CONCEPTUAL MODEL

A preliminary qualitative risk assessment has been carried out using the source-pathway-receptor principle to create a conceptual model for the site.

As such, potential sources of contamination and potential receptors have been assessed using the Contaminated Land Exposure Assessment (CLEA) Guidelines. The fact that a pathway must exist between a potential source of contamination and a potential receptor for there to be a risk, has been taken into account.

The results of the desk study and walkover indicate that the following potential sources of ground contamination are present at or in close proximity to the site:

- Made Ground is likely to be present at the site associated with demolition of historical structures.
- A gravel pit is recorded on site. The topography suggests that has not been infilled however investigations are considered necessary to confirm this assumption.

The following most sensitive receptors have been identified at the site:

Human Health

- End users of the site (residents/staff)
- Surrounding residents
- Construction workers

Environmental

- Controlled Waters - the pond 15m to the south east of the site.
- Controlled Waters - the watercourse 32m to the south east of the site
- Controlled Waters - the Secondary Aquifer and Principal Aquifer beneath the site.

It is considered that a number of potential pathways exist between these potential sources and the above identified receptors.

For the human receptors these include:

- Direct soil ingestion in areas of exposed soil.
- Ingestion of soil attached to home-grown fruit and vegetables.
- Ingestion of fruit and vegetables with contamination uptake.
- Inhalation of indoor and outdoor vapours and dust.
- Dermal contact with contaminated soil.
- Inhalation of soil gases or vapours migrating through permeable strata into the building.

For the environmental receptors the pathways include:

- Migration of contaminants through the unsaturated zone.
- Migration of contaminants through the groundwater.
- Movement of contaminants through drains or services runs.
- Run-off to the nearby watercourse.
- Migration of soil gases through permeable strata.

EXPLORATION AND TESTING

GENERAL

A total of fourteen exploratory holes were formed at the site, inclusive of nine machine excavated trial pits, two hand augered boreholes and three cable percussion boreholes between the 14th and 26th November 2013. The logs are provided in Appendix B.

SAMPLING STRATEGY

The positions of the exploratory holes were selected by Listers Geotechnical Consultants to provide a wide coverage of information on the site area. Access was not available with the cable percussive rig to the overgrown area within the southern parts of the site or to the rear garden of the existing house. Machine excavated trial pits were also avoided in the rear garden area and was not accessible to the localised depression located in the southern part of the site.

As the desk study and walkover survey had identified a number of potential pollution sources at the site several of the exploratory holes were targeted on these sources. These included:

Target	Exploratory Hole
Gravel Pit	HA1, TP1
Former structures and old fires	TP8
Suspected area of glass infilled pit from former glass house	TP5, BH3
Raised landscaped mound/imported Topsoil	HA2
Imported Topsoil	TP5, TP6, TP7, TP8, BH1, BH3

The other exploratory holes were positioned in order to provide a spread of information.

The position of all exploratory holes undertaken at the site as part of this investigation can be seen on the Exploratory Hole Location Plans in Appendix A. The results of the laboratory testing are provided in Appendix C.

METHODOLOGY

The trial pits, TP1 to TP9 were excavated with a JCB type backhoe excavator to a maximum depth of 3.2m below ground level. Small-disturbed samples were taken at regular intervals down to the base of the holes for subsequent laboratory testing and inspection. In-situ measurements of shear strength were taken using a hand shear vane, where applicable. On completion, all trial pits were carefully backfilled with arisings in thin layers, ensuring that excavated material was replaced in the same order as it had been removed.

Boreholes BH1 to BH3 were drilled utilising a standard cable percussion rig, at a diameter of 150mm, down to a maximum depth of 12m below ground level. Metal casing was extended to a maximum depth of 7m, to avoid the collapse of the loose deposits within the upper part of the boreholes and seal out groundwater inflows. Disturbed samples were collected at regular intervals throughout the borehole for future laboratory inspection and testing. Standard penetration tests (SPTs) or undisturbed tube samples (U100s) were taken at 1.0m intervals down to the base of each borehole.

On completion of the boring, boreholes BH2 and BH3 were utilised for the installation of a 50mm diameter slotted uPVC standpipe from the base of the borehole up to within 6m below existing ground level. From 1m depth up to ground level a plain pipe was added. The slotted section of the standpipe was surrounded with pea gravel, while expansive bentonite clay was added around the plain pipe and below the slotted section to seal the borehole. The standpipe was finished with a stopcock cover, which was then concreted flush with ground level.

Boreholes HA1 to HA2 were put down using a Dutch portable hand auger to a maximum depth of 1m below existing ground level. The 55mm diameter auger head was rotated and pushed down into the soil by means of a T-handle to obtain selected disturbed soil samples at regular intervals.

Engineering and geoenvironmental conclusions given in this report are based on data obtained from these sources but it should be noted that variations, which affect these conclusions, may occur between and beyond the test locations. Also water levels may vary with time.

GROUND CONDITIONS

The site and laboratory test work revealed that the general succession of strata can be represented by Head overlying London Clay Formation and Lambeth Group deposits. It may be summarised as follows:

Topsoil/Made Ground - Topsoil was generally encountered at each location from surface down to depths of approximately 0.2m in the southern parts of the site and between 0.5m and 1m in the paddock area where imported Topsoil is understood to have been introduced. At TP9 and BH2 locations Made Ground was recorded which comprised Topsoil up to 0.2m depth with pockets of ash and isolated brick fragments. This in turn was underlain with a band of brick and flint gravel at BH2 location which extended to 1m depth. Made Ground was also present at the location of TP3 and TP8. TP3 included various metal car parts and a rubber tyre while TP8 encountered occasional ceramic, brick and metal fragments. The landscaped mound within the rear garden comprised a thin veneer of Topsoil on top of firm clay with occasional chalk, brick and flint gravel.

Classification tests on selected samples revealed moisture contents ranging from 23% to 38%. Localised clay Made Ground at HAI location recorded the fines fraction to be classified as a soil of medium volume change potential in accordance with NHBC Building Standards, Chapter 4.2.

Loss on ignition tests revealed an organic content of between 4% and 9%.

Head deposits - encountered at each test location where the base of the Made Ground was proven from between 0.2m and 1m depth down to depths of between 6.8m and 1.6m where the full depth was proven. The Head deposits reduced in thickness from the north to the south east of the site, where site levels were at their lowest. The Head deposits were represented in general by a variable mix of orange brown and brown sandy gravel, with variable proportions of clay, and firm through to stiff slightly gravelly clay. Infrequent soft clay lenses were noted within the predominantly granular soils, which are considered to be as a result of perched groundwater seepages.

Classification tests on selected samples revealed moisture contents ranging from 6% to 40% with the fines fraction classified as a soil of medium

volume change potential in accordance with NHBC Building Standards, Chapter 4.2.

Full laboratory sieve analyses on the more granular soil horizons revealed these to be clayey sandy gravel.

Undrained triaxial compression tests undertaken on undisturbed samples revealed shear strengths ranging from 10kPa to 55kPa however it is considered that some tests failed prematurely along gravel lenses. Corresponding laboratory hand vane tests on the same samples revealed undrained shear strengths ranging from 20kPa to 84kPa.

Shear vane tests undertaken in the field in samples from the trial pits revealed undrained shear strengths ranging from 73kPa to 130kPa.

'N' values derived from standard penetration tests in the boreholes ranged from 20 to in excess of 50 reflecting the variability of the deposit.

The number of blows taken to retrieve an undisturbed U100 tube sample from the boreholes ranged between 60 and 80.

Loss on ignition tests revealed an organic content of 4%.

London Clay Formation - encountered within the northern part of the site in the boreholes from between 5.0m and 6.8m depth continuing down to beyond the base of the boreholes at 12.0m. Represented in general by a firm becoming stiff blue grey fissured silty slightly sandy clay.

Classification tests on selected samples revealed moisture contents ranging from 17% to 43% with the fines fraction classified as a soil of medium volume change potential in accordance with NHBC Building Standards, Chapter 4.2.

An undrained triaxial compression test undertaken on an undisturbed sample revealed a shear strength of 21kPa however it is considered that this tests failed prematurely along a pre-existing fissures. A corresponding laboratory hand vane test on the same sample recorded average undrained shear strength of 124kPa. Further hand vane tests and pocket penetrometer tests converted to approximate shear strength ranged from 26kPa to 175kPa with the lower bound results considered to be due to localised softening during the drilling process as a result of an isolated groundwater seepage.

‘N’ values derived from standard penetration tests in the boreholes ranged from 19 to 27 with a slight increase with depth.

The number of blows taken to retrieve an undisturbed U100 tube sample from the boreholes ranged between 100 and 110.

Lambeth Group -

encountered within the trial pits in the southern and south eastern parts of the site at depths between 1.6m and 2.6m and continued down to beyond the base of the pits at a maximum depth of 3.2m below ground level. Represented in general by stiff light brown and light orange brown, slightly sandy, clay and very silty, fine sand with clay laminations and gravelly beds.

Classification tests on selected samples revealed moisture contents ranging from 20% to 33% with the fines fraction classified as a soil of medium volume change potential in accordance with NHBC Building Standards, Chapter 4.2.

Full laboratory sieve analyses on the more granular soil horizons revealed these to be silty very gravelly sand.

Shear vane tests undertaken in the field in samples from the trial pits revealed undrained shear strengths ranging from 90kPa to 159kPa.

California Bearing Ratio (CBR) Tests

CBR tests were undertaken in the Head deposits encountered at the site. Results of the testing ranged between <1% and 4%.

Sulphate and pH Tests

Soluble sulphate tests carried out on soil samples recovered from the exploratory holes recorded values ranging from 0.13g/l to 0.52g/l, in conjunction with pH values ranging from 6.7 to 8.4.

GROUNDWATER

Ground water seepages/inflows were encountered within the Head deposits and the granular Lambeth Group deposits at depths of between 0.9m to 5.5m. Entries were also recorded within the London Clay Formation at depths of 6.5m and 7.5m below the existing ground level.

Monitoring carried out as part of the project has recorded standing water at 2.02 and 2.95m at BH2 location and 0.67m and 2.02m at BH3 location.

OBSERVED SOIL CONTAMINATION

No obvious evidence of prevalent contamination was noted during the fieldwork however Topsoil/Made Ground was encountered in isolated areas which contained brick and ash fragments.

SOAKAWAY TESTING

Soakaway testing was carried out in the Head strata encountered at the site. The tests were undertaken within a standpipe installation in borehole BH2 to provide indicative infiltration results broadly following the principals of BRE Digest 365 'Soakaway Design'. Testing was not undertaken in BH3 as this standpipe was flooded at the time of our visit.

The infiltration results ranged between 4.0×10^{-3} m/s and 6.6×10^{-3} m/s.

GROUND GAS

Ground gas monitoring carried out as a part of this investigation has revealed oxygen levels of between 14.7% and 17.7% by volume, carbon dioxide levels of between 2.7% and 5.1% by volume, and methane levels of 0.2% and 0.3% by volume.

Flow rates of 0.0l/hr and 0.1l/hr were recorded. These low flow rates are indicative of the soils encountered which did not include any significant thicknesses of Made Ground, or have any significant quantities of organic matter or materials which can decay.

The results are provided in Appendix B.

GROUND CONTAMINATION ASSESSMENT

SOIL TESTING

Six samples of the Made Ground/Topsoil and one sample of the natural soils collected on site during this investigation were tested for a range of contaminants. Several of the samples to be tested were recovered from the test locations targeting the potential sources of contamination identified in the desk study and during the site walk over.

The suite of testing carried out on the samples was decided upon following consultation of R&D CLR Publications, published as part of the Contaminated Land Exposure Assessment (CLEA), a joint venture between the Department for Environment, Food and Rural Affairs (DEFRA) and the Environment Agency.

The test suite included a range of:

- Metals and inorganic substances
- Speciated Polyaromatic Hydrocarbons (PAH)
- Total Petroleum Hydrocarbons (TPH), with eight band split
- Asbestos screening

The soil samples were tested to obtain 'Total' values within the soil.

In addition, two soil samples were also tested from a solution obtained using the NRA R&D301 leachate procedure, simulating contaminant leachability to underlying groundwater.

The results of the tests from this investigation are included in Appendix C.

RISK ASSESSMENT GUIDELINES – HUMAN HEALTH

The human health risk assessment has been undertaken using the guidance provided in the Environment Agency's publication CLR11, Model Procedures for the Management of Contaminated Land, published in September 2004. Human health assessment criteria used are based upon the proposed final land use of the site, in this case the guidelines for 'Residential with home-grown produce' have been used as an initial screening tool.

Currently in the UK, no statutory limits for the presence of contaminants in soils or groundwater exist. Therefore, the results of the soil samples tested are compared to the following environmental quality standards:

Category 4 Screening Levels (C4SLs)

Published in March 2014 by DEFRA, C4SLs were primarily produced to support the revised Statutory Guidance to support Part 2A of the Environmental Protection Act 1990, which was published in April 2012. This Guidance introduced a new four-category system for classifying land under Part 2A for cases of a Significant Possibility of Significant Harm to human health, where Category 1 includes land where the level of risk is clearly unacceptable and Category 4 includes land where the level of risk posed is acceptably low.

With regards to using the C4SLs for planning purposes the DEFRA letter of 3rd September 2014 from Lord de Mauley established that they are also meant for use in planning situations, as does the DCLGs 'Planning Portal' document 2014.

Suitable 4 Use Levels (S4ULs)

As well as limited number of C4SLs (and where C4SLs are not available), the set of S4ULs produced by Land Quality Management (LQM) and the Chartered Institute of Environmental Health (CIEH) in 2015 using the CLEA software, are used as a screening tool.

The CLEA software 1.06 version was released in October 2009 and is a deterministic exposure model with altered exposure data to the original model. The model allows the creation of a generic assessment criteria database with which to screen laboratory testing results. These generic assessment criteria are conservative and based upon common assumptions.

RISK ASSESSMENT GUIDELINES – GROUNDWATER

The procedures set out in Environment Agency's Remedial Targets Methodology *Hydrogeological risk assessment for contaminated land* (2006), have been followed.

The test results are compared to the UK Drinking Water Standards (UKDWS) set out in The Water Supply (Water Quality) Regulations 2000. Where the environmental setting is sensitive, results are also compared to the Environmental Quality Standards (EQS) as set out in the EC Dangerous Substances Directive (76/464/EEC).

Several of the EQS contaminants are dependent on the hardness of the receiving watercourse. In this area chalk deposits are present and Southern Water indicates water pumped from underground sources in the chalk at Burpham, Angmering and Patching has hardness in the order of 275CaCO₃ mg/l and hard water conditions are present based on the local geology. This information has therefore been used to aid our assessment.

RESULTS OF TOTAL SOIL TESTS

Asbestos screening did not detect asbestos and hence the risk from this contaminant is considered to be low.

Of all the contaminants tested a number recorded values higher than their relevant environmental standard value for human health for a residential setting.

The results of the analyses are described below and presented in Appendix C of this report.

Lead

Of the seven samples tested, the values obtained ranged from 13mg/kg to 1200mg/kg with two samples exceeding the C4SL of 200mg/kg.

The elevated concentrations were recorded within localised areas of Made Ground at HA1 and HA2 locations where clay with isolated brick fragments was encountered. This corresponds to the clay core within the landscaped bund within the existing rear garden and a thin clay band at the base of the former gravel pit some 1.5m to 2m lower than the surrounding site topography.

Benzo(b)flouranthene, Benzo(a)pyrene

These two contaminants are part of the family of polycyclic aromatic hydrocarbon compounds (PAHs) and of the seven samples tested only one sample exceeded the S4UL of 3.0mg/kg for benzo(a)pyrene (BaP) and 3.7mg/kg for benzo(b)flouranthene with recorded values of 5.6mg/kg and 7.3mg/kg respectively.

The elevated results correspond to the near surface Made Ground at HA1 location where brick fragments were recorded within a thin layer of soft clay.

We understand the new care home is proposed in this area, in addition it is considered likely that existing levels will need to be raised in the order of 2m to 2.5m to accommodate the new building. It is therefore considered that the incorporation of the new building and raising site levels with clean material will effectively sever the pathway to end users from these contaminants.



Dibenzo(a,h)anthracene

Dibenzo(a,h)anthracene is also a PAH and of the seven samples tested, the values obtained ranged from <0.1mg/kg to 0.92mg/kg with four results exceeding the S4UL of 0.3mg/kg. The elevated concentrations correspond to the Made Ground soils at TP3, TP9, HA1 and HA2 locations, where various anthropogenic materials were noted such as brick, ash, and metal car parts. Such deposits are not considered to be widespread at the site however one of the elevated results corresponds to the clay core within the landscaped bund in the rear garden. Should this material be proposed for reuse in garden/landscaped areas then further testing is recommended to determine its suitability or alternatively remedial measures undertaken as detailed later in this report. The contamination at TP9 location is considered to be attributed to ash within the Topsoil at this location. The extent of the ash within the Topsoil has not been established. Where such deposits remain in garden/landscaped areas then suitable precautionary remedial measures are recommended across this area.

RESULTS OF LEACHATE TESTS

Of the two samples tested neither recorded values in excess of the respective guideline values adopted.

HUMAN HEALTH RISK ASSESSMENT

The following qualitative risk assessment has been carried out using the source-pathway-receptor principle. As such, potential sources of contamination have been assessed using the CLEA Guidelines. The fact that a pathway must exist between a potential source and potential receptor for there to be a risk, has been taken into account. The potential human receptors evaluated for their individual risk are:

- End users of the site (residents, staff).
- Surrounding residents.
- Construction workers.

GENERAL

Elevated lead, BaP, benzo(b)fluoranthene and dibenzo(a,h)anthracene were encountered at concentrations above corresponding guideline screening values.

It is considered that the elevated BaP and benzo(b)fluoranthene corresponds to localised Made Ground within the base of the former pit within the southern part of the site. It is considered likely that existing levels will need to be raised in the order of 2m to 2.5m to accommodate the new care building in this area. It is therefore considered that the incorporation of the new building and raising site levels with clean material will effectively sever the pathway to end users from these contaminants. Hence these contaminants are considered unlikely to pose a significant risk to human end users.



Elsewhere elevated lead and dibenzo(a,h)anthracene was encountered which are considered to be as a result of anthropogenic fragments within the Made Ground at isolated locations at the site. Remedial measures or further investigation are therefore considered necessary in these areas to minimise the risk to human health or further quantify the risks.

END USERS OF THE SITE

The elevated concentrations of lead and dibenzo(a,h)anthracene encountered within the Made Ground soils in the have the potential to cause significant harm to the end users of the site if direct contact to them is available to the end users from such routes as soil ingestion or inhalation of dust.

The contamination has been shown not to be widespread across the site, but appears to exist in localised areas. Based on the development proposals it is considered that much of the contaminated soils are likely to be covered by new buildings and the care home however should such deposits remain in proposed gardens or areas of landscaping then suitable precautions will be necessary.

It is therefore considered that it may be necessary to implement remedial measures at the site to break the source-pathway-receptor linkage between the contaminated soils and the end users.

SURROUNDING RESIDENTS/STAFF/WORKERS

The guideline values listed above have been calculated with the most sensitive receptor in mind, the end users of the site. As such, remedial measures produced to safeguard the health and eliminate the risk to this receptor will also reduce the risk for surrounding residents.

Therefore, the conclusions made for the end users are also relevant to the slightly less sensitive surrounding population.

CONSTRUCTION WORKERS

The exposure route of primary concern for the contamination is 'direct soil ingestion'. For the construction workers there is a direct link to the soil when they undertake the site work and therefore different measures should be taken to manage the short-term exposure risk of coming into contact with contaminated soil.

To reduce the risk to as low as reasonably practicable for the construction workers it is recommended that appropriate health and safety measures be implemented along with the use of Personal Protective Equipment (PPE). All personnel coming into contact with the soil, ground workers in particular, should be instructed to use gloves when on site to avoid dermal contact and restrict inadvertent hand-to-mouth ingestion. Washing facilities should be provided for the site staff to use, and should be used prior to eating or smoking. Reference should be made to the HSE Document, "Protection of Workers and the General Public during Development of Contaminated Land".

REMEDIAL MEASURES

Elevated concentrations of lead and dibenzo(a,h)anthracene have been recorded within soil samples collected from the site.

It has been established that these potentially pose a significant risk to both end users of the site in gardens and areas of landscaping, the surrounding residents and the construction workers involved in the development of the site. The contamination is not generally considered to be widespread and is likely to be attributed to anthropogenic materials such as Topsoil with ash and car parts at TP9 and TP3 location respectively and within the clay core of the landscaped bund on site. An indicative plan showing the estimated extent of the contaminated soils is presented in Appendix A. In these areas the following remedial solutions are suggested:

- i. **Cover system:** removal of the pathway between the contaminated soil and end users, by adding a carefully designed cover layer in areas of domestic gardens and soft landscaped areas on the site. This would work by reducing the risk to acceptable levels /removing the pathway and so breaking the pollutant linkage.

We recommend a **clean** topsoil cover thickness of 600mm should be adopted in gardens capable of cultivating home-grown produce, assuming the imported material is *certified clean prior to use*.

This may be undertaken by either raising site levels or removing some of the soil to create the depth required. In our opinion a reduced thickness of 300mm may be acceptable in less sensitive landscaped areas and front gardens however we recommend approval is sought from the Local Authority regarding the minimum cover thicknesses required at this site.

- ii. **Remove source:** removal of the contaminated Made Ground soil, followed by validation testing to confirm the residual soils pose a low risk to human health. Following this exercise a nominal thickness of clean material may be introduced. This applies to the gardens and soft landscaped areas at the site.

For disposal details of these soils reference should be made to the DISPOSAL OF WASTE MATERIAL section at the end of this report. Alternatively, the soil may be suitable for re-use on site, see the section titled RE-USE OF MATERIAL ON SITE.

To reduce the risk to as low as reasonably practicable for the construction worker it is recommended that, high standards of personal hygiene should always be maintained amongst site personnel at all times. All personnel coming into contact with the soil, ground workers in particular, should be instructed to use gloves when on site. Washing facilities should also be provided and used prior to eating or smoking to prevent any hand to mouth transfer. Should any visual or olfactory evidence of

contamination be encountered during the construction phase, work should be suspended and further advice should be sought.

Regulatory Approval

Any finalised remedial measures concerning human health will need to be approved by the relevant Local Authority Environmental Health Department or the NHBC prior to development. These should be accompanied with a copy of this report and any subsequent investigation reports.

Once remediation methods have been finalised it is recommended that a remediation strategy is written so that all parties involved in the development are clear about the chosen methods, implementation programmes and verification testing regimes that are required.

FURTHER WORK

The contaminated Made Ground is considered to be localised at the location of TP3 and is likely to be associated with isolated car parts at this location. The extent of the contamination at TP9 location in the Topsoil with ash pockets is not known at this stage. Further testing may be undertaken in order to delineate the area of contaminated Made Ground at this location.

Should the existing clay core within the landscaped bund be proposed for reuse the supplementary testing may be undertaken to determine its suitability as bulk fill in garden/landscaped areas or suitable precautionary remedial measures, as detailed above, undertaken.

VALIDATION TESTING

In garden and landscaped areas where remedial works are required then validation of the imported topsoil/sub soil thicknesses will be necessary along with testing certificates demonstrating the imported soils are suitable for use as discussed below. Alternatively where the Made Ground soils are completely removed then validation testing of the residual soils is recommended to demonstrate the remaining soils pose a low risk to human health.

Imported Topsoil and Subsoil Specification

Any new soil imported to the site should have been tested for a range of chemicals or determinants by the supplier. The TPH analysis should ideally have a breakdown of the carbon banding ranges.

The concentrations of determinants required in the topsoil must take into account the thickness of the cover system that is being implemented in the gardens at the site and the concentrations of any elevated levels of contaminants in the soil beneath.

To ensure that the requirements of the 600mm cover system are fulfilled, any imported subsoil or topsoil should contain levels of contaminants at or below the current guideline values.

It should be noted that newly placed topsoil will settle over time and may not then fulfil the full thickness requirement of the cover system. Consideration to a combination of subsoil and topsoil should be given to reduce this effect.

POST REMEDIATION VERIFICATION

Any remedial measures undertaken at the site will require independent verification once completed to ensure the pollutant linkage to the end users of the site has been removed. This is undertaken to satisfy the relevant regulatory authorities and other interested parties, including future owners of the site, banks, insurers and mortgage companies. This usually involves a small validation investigation to confirm that the remediation has been successful.

Any soil imported to the site should be accompanied by a certificate of chemical analysis. Otherwise, further testing for contaminants must be undertaken to demonstrate that the imported soils are clean. The engineer performing the verification will need to see the soil testing results to validate the imported soil prior to the cover system being constructed to ensure that it is suitable for use.

More commonly, regulators wish to see independent testing on the imported soil to confirm its suitability in addition to the original certificate of analysis.

If the imported soil was found to be unsuitable, it would need removal and replacing with new clean soil.

GROUNDWATER RISK ASSESSMENT

The following risk assessment has, again, been carried out using the source-pathway-receptor principle. The procedures set out in the Environment Agency's Remedial Targets Methodology *Hydrogeological risk assessment for contaminated land* (2006), have been followed. Results have been compared to the UK Drinking Water Standards and to the available Environmental Quality Standards (EQS). The potential environmental receptors considered during this risk assessment were:

- Controlled Waters - the pond 15m to the south east of the site.
- Controlled Waters - the watercourse 32m to the south east of the site
- Controlled Waters - the Secondary Aquifer and Principal Aquifer beneath the site.

GENERAL

Of the contaminants tested for within the leachate samples, none recorded values in excess of their respective EQS or UKDWS. It is therefore considered that the above recognised environmental receptors are unlikely to be at significant risk from potential groundwater pollution at the site.

The Environment Agency is the regulatory body charged with protection of controlled waters and may be a consultee in the planning process. We recommend that the conclusions of this report are agreed with the relevant Local Authority at the earliest stage, to reduce potential delays to the development.

GEOTECHNICAL ENGINEERING CONCLUSIONS

GENERAL

The development proposals has not been finalised however involves the construction of a new care home building and several two storey houses. We understand ground levels will be raised in some parts in the order of 1.3m and new retaining walls constructed to maintain level areas. Cuttings into the existing ground surface are generally not anticipated at the site however towards the north western site boundary and in the central part of the site sections of ground may be reduced by up to 1m. Plans showing the development proposals including the proposed sections are presented in Appendix A.

The exploratory work from this investigation differed from the geological maps with London Clay Formation sub cropping beneath Head deposits in the northern part of the site. The Tarrant Chalk Member, recorded sub cropping beneath Head deposits in the extreme south eastern corner of the site by the geological maps, was also not encountered during the course of our investigations.

The investigations encountered Topsoil/Made Ground overlying suspected Head deposits, which in turn directly overlie the London Clay Formation in the northern part of the site and the Lambeth Group in the southern and eastern parts of the site. The thickness of the Lambeth Group and depth to the underlying chalk was not established however it is considered likely to extend beyond 3m depth below existing site levels. Similarly the London Clay deposits will thin towards the south where the underlying Lambeth Group is present.

The Topsoil/Made Ground extended to depths of between 0.15m and 1.0m below the existing ground surface. The Head deposits extended to depths of between 0.9m towards the lowest site level in the southern parts of the site (TP3) to 6.8m in the north eastern part of the site (BH1). The Head deposits were variable and generally comprised medium dense through to very dense flint gravel with varying proportions of clay and sand intermixed with firm through to stiff clay deposits. Localised soft clay lenses were recorded at BH2 location. The London Clay Formation, encountered in the northern parts of the site, comprised firm becoming stiff blue grey clay, which was fissured and included sandy horizons at some locations. The Lambeth Group encountered in the southern and eastern parts of the site at depths of between 0.9m and 2.6m below existing ground levels and generally comprised stiff light brown and light orange brown clay and light brown very silty fine sand.

Ground water seepages/inflows were encountered within the Head deposits and the granular Lambeth Group deposits at depths of between 0.9m to 5.5m. Entries were also recorded within the London Clay Formation at depths of 6.5m and 7.5m below the existing ground level. The groundwater seepages are considered likely to represent perched entries contained within the variable granular Head deposits, with more significant inflows towards the base of the existing slope contained within the granular Lambeth Group. Monitoring as part of this investigation has recorded standing water at 2.02 and 2.95m at BH2 location and 0.67m and 2.02m at BH3 location.

The laboratory testing shows the cohesive Head, Lambeth Group and London Clay Formation to have a medium volume change potential as defined by NHBC Building Standards, Chapter 4.2.

SITE EXCAVATION

Conventional hydraulic plant should be satisfactory for excavating foundation and service trenches within the soils however specialist breaking plant will be required to assist in the removal of concrete slabs at the site.

In line with HSE guidelines, all excavations requiring personnel access should be adequately supported to avoid the risk of collapse. Shallow excavations (say <1m below existing site levels) within the soils are likely to remain stable in the short term. Excavations below 1m however are likely to be at increased risk of encountering seepages/inflows, which will affect the stability of trenches and may hamper trench excavations, particularly in the southern and eastern parts of the site.

Perched groundwater seepages are likely to be encountered within excavations through the Head deposits, particularly following wet periods. It is considered that such entries may be controlled using conventional pumping from sumps for trench excavations however more significant control measures may be necessary if the proposals include cutting into the existing slope or where excavations extend into the granular Lambeth Group deposits, encountered towards the southern and eastern parts of the site. In this respect we recommend the advice of a specialist dewatering contractor should be obtained. The effects of dewatering on adjacent infrastructure will also need to be taken into account as dewatering could result in settlement and induce localised instability.

It would be prudent to carry out all ground works in the late summer or autumn when groundwater levels and flows are usually at their lowest.

Slope stability aspects are outside our brief however consideration will be necessary to ensure the existing slope stability is not compromised as groundwater entries will promote excavation collapse.

An area of deepened Made Ground is suspected in the southern part of the existing paddock area as a result of burying glass from the former glass house on the site. The location and extent of this feature was not proven during this phase of works however we understand the excavation measured some 15 feet by 15 feet (4.6m by 4.6m) and is approximately 12-15 feet deep (3.7 to 4.6m). We recommend suitable contingencies should be allocated, should such deposits be encountered, which may include full trench support to maintain an open excavation.

Should cuttings into the site be proposed then consideration will also be necessary to possible heave movements within the cohesive soils. Based on cutting excavations of less than 1m in depth then the magnitude of potential heave is likely to be negligible. Further consideration will be needed however should the current proposals be altered and cutting excavations extend below this depth. Heave recovery may also occur as a result of the removal of trees and large shrubs in the southern part of the site.

Consideration should be given to the effects of trees and shrubs on service runs that cross the site. Soil movements brought on by the influence of vegetation can severely disrupt drain runs and mains services, and measures should be incorporated into the excavations to allow for future ground movements.

FOUNDATION SOLUTIONS

Shallow Foundations

In our opinion, the natural soils may be capable of supporting the buildings on strip/trench fill foundations at not less than 1m below existing ground level or 0.20m into the top of the natural formation, whichever is the deeper. However the site falls some 7m from the north to the south and hence it is considered that retaining walls are likely to be required and hence the viability of trench fill will be dependent on final site level proposals.

An allowable bearing capacity of 120kPa may be adopted for foundations not exceeding 1.0m in width founded on the Head, London Clay and Lambeth Group soils. This allows for a factor of safety of three against shear failure and for settlements generally not to exceed 25mm taking place over a number of years. Should any softened deposits be encountered during the course of foundation excavations then excavations should continue to locate stiffer soils or suitable reinforcement introduced to span the soft area. In order to minimise differential settlement of spread foundations spanning variable soils it is recommended that suitable reinforcing be incorporated into the foundations to avoid the occurrence of localised movement and the creation of hard spots.



A former gravel pit is recorded on the site towards the western boundary. A depression was noted at the location of the former gravel pit suggesting this feature has not been subsequently infilled. A shallow hand auger undertaken at the base of depression however recorded Made Ground at this location comprising naturally derived clay deposits. In view of the limited extent of the pit and the proximity of Dappers Lane which was present at the time of the pit, it is considered unlikely that the Made Ground extends to significant depth. Further investigation is recommended however in order to determine the full thickness of the Made Ground soils in order to determine the viability of trench fill foundations at this location.

Consideration should also be given to deepened Made Ground associated with a localised infilled area containing glass from the former glass house. Deepened trench fill will be required in this area to extend below the base of the Made Ground, or alternatively given the likely depth anticipated, appropriate reinforcement introduced to span the area. Further investigation works may be undertaken in an attempt to determine the location and extent of the infilled area in order to enable appropriate foundation design.

Where foundations within are to be constructed within the vicinity of trees or shrubs then they will require deepening in accord with guidelines given in NHBC Building Standards Chapter 4.2. We recommend the cohesive soils should be considered as being of medium volume change potential.

Should the above bearing pressures prove insufficient or final site levels and dewatering considerations preclude the effective use of trench fill foundations, then foundations could be supported on piles extending into the underlying London Clay Formation and Lambeth Group strata.

Pile Foundations

Should the above quoted allowable bearing pressure prove insufficient or problems with dewatering prove difficult, foundations could be supported on piles founded within the underlying Head, London Clay, Lambeth Group and possibly the underlying Tarrent Chalk Member.

The full thickness of the Lambeth Group deposits has not been established in the southern parts of the site or the London Clay Formation in the northern and central parts of the site. In view of the recorded geology in the area it should be appreciated that piles may extend through the London Clay and into the underlying Lambeth Group at some locations. Similarly towards the southern and western parts of the site piles may extend through the Lambeth Group and into the underlying Tarrent Chalk Member. Due to access restrictions our borehole excavations were limited to the northern and eastern parts of the site where London Clay Formation soils were proven to the full extent of the boreholes. Hence should a piled foundation solution be sought we recommend supplementary boreholes are undertaken in western and southern areas of the site, extending below the influence of proposed piles lengths, to provide

information within the Lambeth Group deposits and determine the competency of the underlying chalk, if present, to enable suitable pile design.

Consideration will therefore be necessary to the presence of variable deposits as discussed above which include a combination of cohesive soils, granular soils and variable bedrock geology, as well as groundwater entries within the natural deposits at variable depths.

A preliminary pile design data sheet of ultimate values for bored piles through the Head and London Clay Formation in the northern part of the site is included in Appendix A, based on information to date. The design sheet will require updating following any supplementary boreholes at the site.

The ultimate shaft friction and the end bearing has been calculated using the result of the standard penetration tests in conjunction with recognised conversion factors and laboratory test data. We recommend any support from the Made Ground is ignored. In addition, consideration will be required to final site levels when designing piles.

In view of the complex ground conditions present at this site, the advice of a specialist piling contractor should be obtained to determine the most appropriate pile type and its design. Given the presence of groundwater, particularly in the southern parts of the site, care will need to be taken to avoid the occurrence of necking of bored cast in place piles.

Where piles are located within influence of trees/hedgerows at the site and cohesive soils are present, including the recently removed vegetation, then piles should be sleeved within the zone of desiccation and void formers used beneath ground beams to reduce the effects of any localised heave recovery of the soil should the trees be removed or die. This sleeving will also act to minimise the effects of seasonal uplift forces within the root zone.

If pile load tests are carried out an appropriate factor of safety would be 2.5. If it is not expected to carry out such tests then the factor of safety should be increased to 3.0.

GROUND FLOOR SLABS

Provided all the Topsoil and Made Ground is stripped off, ground bearing floor slabs could be constructed placed on a layer of well compacted granular fill. However where it is required to deepen the main foundations below 1.50m depth, due to the presence of trees and large shrubs (existing or in areas of recent vegetation) or where seasonal desiccation is occurring then ground floor slabs will require suspending in accord with NHBC guidelines. A void should be left below the floor slab to accommodate future soil movements. This may be achieved by use of a proprietary compressible material such as Clay board or Cellcore.

It should be noted that in accord with NHBC guidelines, a suspended floor slab will be required in soils with a volume change potential, even in the absence of trees and shrubs, where the soil is seasonally desiccated. Under those circumstances the adoption of a suspended slab is only likely to be avoided if construction of the floor slab takes place during the wetter times of the year. A void should be left below the floor slab to accommodate future soil movements. This may be achieved by use of a proprietary compressible material such as Clay board or Cellcore.

The NHBC Standards Chapter 4.2 provides useful guidance for determining the theoretical influence of trees on clay soils based on the volume change potential, the tree heights (including mature heights), tree species and distances from the building. We recommend the advice is sought from a qualified Arboriculturalist with regard to the tree species/mature heights on site, to aid determining the potential zones of influence.

GAS PROTECTION

The risk of ground gases impacting the site was assessed by reference to the paper "A pragmatic approach to ground gas risk assessment for the 21st Century" Card and Wilson, 2011. This is a follow up paper to the CIRIA Report 665 and is compatible with that document.

A former gravel pit is recorded on the site towards the western boundary. The historical maps indicate this was fairly limited in lateral extent and during our site walk over a depression was noted at the location of the former gravel pit suggesting this feature has not been subsequently infilled. A hand auger undertaken at the base of depression recorded Made Ground at this location however this comprised naturally derived clay deposits. Based on this information it is considered unlikely that the gravel pit presents a significant risk from ground gases at the site.

The results of the gas monitoring have revealed that carbon dioxide gas up to 5.1% are being produced in the ground while low levels of methane gas up to 0.3% was recorded. Flows rates of 0.0l/hr and 0.1l/hr were recorded.

The low flow rates indicate that no significant volumes of gas being produced in the ground. There was no organic rich soil and no significant thickness of Made Ground at the site.

The results have been evaluated with reference to Code of practice for the characterization and remediation from ground gas in affected developments, BS8485:2007.

Using the maximum carbon dioxide reading of 5.1% with the highest recorded flow rate of 0.1l/hr, the maximum gas screening value is 0.005l/hr. One result recorded a carbon dioxide levels above 5% however there were no methane levels above 1%. Based on the recorded carbon dioxide concentrations this classifies the site as Characteristic Situation CS2 in accordance with BS8485:2007 and traffic light colour 'Amber 1' in accordance with NHBC Report No 10627 for residential properties. For private



housing, BS8485:2007 would require a solution score level 3 to be incorporated into the design. Various gas protection design systems are detailed in Table 3 of the document in order to achieve this required level of protection. Where NHBC design measures are required then high level gas protection measures will also be necessary. This includes; installing a high level gas protection membrane to create a permeability contrast to prevent ingress of gas into buildings and installed as prescribed in BRE414; incorporating ventilation of the sub floor void designed to provide a minimum of one complete volume change per 24 hours; ensuring membranes used are fitted by a specialist contractor and are fully certified.

The BGS advises that basic radon gas protection measures are necessary.

The above conclusions should be agreed with the relevant local Regulatory Authority as soon as possible prior to development, to reduce any potential delays to the development should they require further clarification of this report or further ground gas monitoring.

WORKING PLATFORMS FOR TRACKED PLANT

If construction on the site requires the use of heavy tracked plant then reference will need to be made to the most recent guide for the design of 'Working Platforms for Tracked Plant', 2004, produced by the BRE.

Use of such plant will require construction of either a working platform or an adequate running surface if the subgrade is determined as being already adequate to support the anticipated plant loadings.

Following removal of the near surface Topsoil and Made ground soils, the subgrade down to 2.0m depth includes cohesive and granular soils. Accordingly, the following soil characteristics should be used for preliminary Working Platform design in accord with the most recent guidance given by the Building Research Establishment. We recommend the platform is designed to the weakest soil, as the granular and cohesive distribution cannot be accurately estimated.

Anticipated Subgrade Characteristics down to 2.00m Depth

	Cohesive and Granular Head	Cohesive and granular Lambeth Group
Undrained Shear Strength C_u of cohesive soil	40kN/m ²	75kN/m ²
Angle of shearing resistance of granular subgrade ϕ 's	30°	30°
Effective unit weight of subgrade material	19kN/m ³	19kN/m ³

It should be noted that soft spots and zones of weaker soil may exist on any site at shallow depth that will have a significant influence on the instability of tracked plant such as the infilled pit containing glass the exact location of which has not been established but is suspected to be in the locality of BH3

and TP5. The location of such features will not readily be determined by a general ground investigation for foundation design and more specific investigation at shallow depth may be required before the design of a working platform can be completed.

The advice of a specialist contractor should be sought to determine the most suitable size and thickness of platform required for their specific plant. This will take into account the size of the plant and anticipated loadings imposed on the working platform.

RETAINING WALL DESIGN

It is proposed to construct retaining walls at the site to facilitate level areas for the development. At the time of writing this report the exact dimensions or method of constructing the retaining walls were not decided however from the preliminary plans provided the retained soils are likely to be in the order of up to 1.3m and will retain infilled soils in the southern part of the site and as a result of a shallow cutting near the northern western boundary.

Hence the design parameters will be dictated by the soils used to raise site levels in this area. Where retaining walls extend below the existing ground surface as part of cut and fill operations then the following parameters may be adopted for the Head deposits:

Parameter	Cohesive Head	Granular Head
c'	0kN/m ² (worst credible) - 5kN/m ²	0kN/m ²
ϕ'	21°	32°
c_u	40kN/m ²	0kN/m ²
γ_b	19kN/m ³	19kN/m ³

CLASSIFICATION OF WASTE MATERIAL

The excavations on site from foundation and services trenches will produce a considerable amount of surplus soil. Under current waste management legislation if this soil is surplus to requirements it will be classified as waste and needs disposing of at a licensed facility. However, some of the soil may be able to be re-used on-site as described in the RE-USE OF MATERIAL ON SITE section below.

If it is decided that the soil should be taken off-site as waste and disposed of, the implementation of the Landfill Directive means that the waste soil requires classification prior to leaving site.

In the event that there is some surplus soil, or soil that is not suitable for use as back fill, under current waste management legislation this soil will be classified as waste and requires classification prior to leaving site.

If it is decided that the soil should be disposed of at a landfill facility, the implementation of the Landfill Directive means that the waste soil require classification under the Waste Acceptance Criteria (WAC).

European Waste Catalogue Determination

A summary of the results of the assessment is provided in Appendix C. The full details of the assessment are available upon request.

Using the 'Total' soil contamination test results from this investigation in conjunction with the HazWasteOnline spreadsheets, some of the soil has been initially classified as **non hazardous, potentially hazardous and hazardous**. Reference has been made to the document WM2 A41 published by the Environment Agency with regard to hazardous wastes. The table below shows the results and the reasons why, after consideration, all the samples are considered to be **non-hazardous**:

Sample No.	Depth	Initial Classification	Reason for initial Classification	Reason to discount initial classification	Final Classification
TP1	0.10	Non-hazardous	-	-	NON-HAZARDOUS
TP3	0.05	Hazardous	Zinc Chromate	No trend in elevated chromium for zinc chromate – Zinc Oxide more likely to be present associated with trace lubricants, linked to the car parts in area, therefore, that used as determinant.	NON-HAZARDOUS
TP5	0.50	Non-hazardous	-	-	NON-HAZARDOUS
TP8	0.10	Non-hazardous	-	-	NON-HAZARDOUS
TP9	0.05	Non-hazardous	-	-	NON-HAZARDOUS
HA1	0.30	Potentially Hazardous	TPH >1mg/kg – Potentially Flammable	Hydrocarbon concentration not high enough for flammability to be relevant.	NON-HAZARDOUS
HA2	0.30	Hazardous	Lead Chromate and TPH >1mg/kg – Potentially Flammable	Hydrocarbon concentration not high enough for flammability to be relevant. No trend in elevated chromium for lead chromate – other lead compounds more likely to be present associated with trace lubricants, linked to the car parts in area, therefore, that used as determinant.	NON-HAZARDOUS

Waste Acceptance Criteria (WAC) Testing Results

To further classify the waste soil for landfill disposal, Waste Acceptance Criteria (WAC) testing has been carried out on a representative sample of the Made Ground at TP9 location. The results show that this soil initially **fails** the **inert** waste criteria due to the levels of Total Organic Carbon (TOC).

The laboratory testing results are presented in Appendix C.

Waste Classification

From the results of the HazWasteOnline spreadsheets and the WAC testing, currently, the waste Made Ground soil on this site is classified as **non-hazardous**. A higher TOC limit value may be permitted by the Environment Agency however at some inert waste landfill sites. **This may allow the Made Ground to be reclassified as inert** as the Dissolved Organic Carbon fraction is well below the acceptance criteria for inert waste. We recommend the analytical results are provided to the landfill operators or waste management contractors to confirm whether it meets their license agreements and to confirm tipping costs.

Uncontaminated soil and stones, including naturally occurring sands and clays, may be accepted in an inert landfill without testing, provided that it is not topsoil or peat and excludes soil from contaminated sites. Inert waste should not undergo change, will not burn, react, biodegrade or adversely affect human health or the environment. It should not contain metals or plastics. In our opinion the natural soils at the site are uncontaminated and may be disposed of as inert waste. We recommend confirmation is sort by the receiving landfill should supplementary testing be required to confirm this.

The Landfill Regulations dictate that all waste must be treated before going to landfill. This treatment should fulfil all of the following three criteria:

- Physical, thermal, chemical or biological process including sorting.
- Change the characteristics of the waste.
- Reduce the volume, reduce the hazardous nature, facilitate its handling or enhance its recovery.

The most basic method of pre-treatment is sorting of the waste and re-cycling any possible materials, many waste disposals companies will have on-site recycling facilities that will be able to undertake this process at the landfill site. However, if treatment would not reduce its quantity or the hazards it poses to human health or the environment, then all three steps may not be necessary. The exception is inert waste for which treatment is not technically feasible.

The Environment Agency expect all landfill operators to obtain written evidence that the waste they accept has been pre-treated. We recommend that a signed certificate should be obtained describing the treatment to give to the receiving landfill. Further testing may be required after the treatment before the soil is accepted by the relevant landfill.



RE-USE OF MATERIAL ON SITE

Currently, if surplus soil is 'fit for re-use' on the site and has not been treated, its re-use is allowed within the planning law. If it needs treating prior to re-use, exemptions can be sought from the Environment Agency to allow this activity.

A recent voluntary code of practice published by CL:AIRE, in conjunction with the EA, (the Definition of Waste: Development Industry Code of Practice, Version 2) endorses the re-use of surplus soil on and off the site of origin without the need for exemptions from the EA, dependent on whether it is "fit for purpose". It also supports the use of "Hub and Cluster" sites (to enable surplus soil to be used on agreed sites in the local vicinity, dependent on the soil being 'fit for purpose').

Based upon the human health and groundwater risk assessments, the Topsoil within the paddock area and the natural soils at this site are considered to be suitable to be re-used on site for bulk fill and garden/landscaping purposes, dependent on the agreement of the Local Authority. The clay core material within the existing landscaped bund may be used as bulk fill beneath buildings however further testing and possibly remedial measures may be necessary should this material be proposed in landscaped/garden areas.

SLOPE STABILITY

The site slopes down from the north to the south with an estimated fall in current ground levels in the order of 7m at an estimated average angle of 4° (1:14) to the horizontal and approximately 9° (1:6) to the horizontal towards the south western corner.

Slope stability aspects are outside the scope of this report however, it should be appreciated that vegetation can reinforce slopes and their recent removal and the subsequent gradual loss of root reinforcement may reduce stability.

Generally the overall slope at the site is not considered to be particularly steep however, the angle increases towards the south western part of the site. In the absence of detailed ground analysis, as a guide consideration should be given to the following to avoid possible instability:

- Increasing/redirecting water flow through the slope (e.g. sheet piling, retaining walls >1m, soakaways).
- Long continuous open foundation/service excavations; say in excess of 10m, parallel to ground contours.
- Unduly loading the slope, such as infilling following ground contours, say 1.5m above existing ground levels.
- Permanent cuttings following ground contours more than say 1m.



SUBSURFACE CONCRETE

With respect to BRE Special Digest 1 'Concrete in Aggressive Ground' (2005), chemical tests on selected soil samples have recorded soluble sulphate concentrations ranging from 0.13g/l to 0.52g/l. The pH values ranged from 6.7 to 8.4.

This would correspond to a Design Sulphate Class of **DS-1** for the Made Ground, Head and Lambeth Group and **DS-2** for the London Clay Formation.

In terms of BRE Special Digest 1, the current land use on the site means that it should be considered to be natural ground.

The groundwater beneath the site should be considered as mobile for the Made Ground, Head and Lambeth Group and static for the London Clay Formation.

Reference to this document indicates that these results correspond to **AC-1** class (ACEC) 'Aggressive Chemical Environment for Concrete' in the Made Ground, Head and Lambeth Group and **AC-1s** for concrete extending into the London Clay Formation.

ACCESS ROADS AND PARKING

The structural design of a road or hard standing is based on the strength of the subgrade, which is assessed on the California Bearing Ratio (CBR) scale. CBR tests were undertaken in the Head deposits encountered at the site with results of the testing ranging between <1% and 4%.

It is recommended that for formation prepared in Head deposits, a subgrade CBR value of 2% is adopted for design purposes. The Head deposits should be considered to be frost susceptible, requiring a minimum pavement construction thickness of 450mm.

The site conditions should be reassessed at the time of construction and the CBR/pavement design updated accordingly if considered necessary.

Any areas of soft or deleterious material should be excavated and replaced with a properly compacted granular fill or alternatively geogrids or similar soil reinforcement techniques should be employed to span the deposits and provide a subgrade with a known CBR value. Discussions should be held with a soil reinforcement company (such as Tensar) who would design a subgrade to a specified CBR value.

SOAKAWAY TESTING

Soakaway tests provided indicative infiltration results between $4.0 \times 10^{-3} \text{m/s}$ and $6.6 \times 10^{-3} \text{m/s}$. The ground conditions at the site however include a chaotic mix of granular soils with varying amounts of clay and clay soils, which are considered likely to be effectively impermeable. It is therefore recommended that supplementary tests are undertaken in machine excavated trial pits in order to more accurately determine the capability of the soils to dispose of storm water using ground infiltration systems.

The Environment Agency does not approve soakaways in contaminated ground. The elevated results for PAHs and lead at this site are within the Made Ground soils at shallow depths and should not be allowed to directly infiltrate into soakaways in contact with the aquifer beneath.

Consideration will however be necessary to shallow groundwater entries, particularly in the southern parts of the site, and to avoid promoting slope instability if such a drainage solution is sought. In this respect, we recommend shallow soakaways up slope or near buildings should be avoided.

Groundwater entries and more cohesive soils may prevent the effective use of soakaways at depth.

UNDERGROUND SERVICES

Elevated levels of lead and various PAHs were recorded in the Made Ground at the site. It should be noted that the utility companies often have their own local guidelines and standards on levels of shallow soil contamination in the ground that may or may not be acceptable for the installation of below ground services. These standards may be different to those specified for assessing risks to human health and groundwater.

The local requirements should be obtained from the particular service supply company as soon as possible to avoid unexpected delays or additional development costs.

Guidance can be sought from the UK Water Industry Research (UKWIR), 'Guidance for the selection of water supply pipes to be used in brownfield sites', reference 10/WM/03/21 and 'Pipe materials selection and specification for use in contaminated land', referenced 04/WM/03/0. These documents propose that the assessment of the hazard to potable water supply pipes should be based on the following pathways: contact with migrating groundwater, permeation of vapour, and direct contact with soil.

Approval should be sought for the type of pipes proposed before they are installed.

Appendix 3 – Calculations

- » *Greenfield Runoff Rates*
- » *Pre-Development Runoff Rates*
- » *Proposed Calculations for the 1 in 100 Year Rainfall Event + 40% Climate Change*

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ICP SUDS Mean Annual Flood

Input

Return Period (years) 100 SAAR (mm) 727 Urban 0.000

Area (ha) 0.326 Soil 0.400 Region Number Region 7

Results l/s

QBAR Rural 1.2

QBAR Urban 1.2

Q100 years 3.7

Q1 year 1.0

Q30 years 2.6

Q100 years 3.7

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STORM SEWER DESIGN by the Modified Rational Method

Design Criteria for Storm

Pipe Sizes AM_Stand Manhole Sizes AM_Stand

FSR Rainfall Model - England and Wales

Return Period (years)	100	PIMP (%)	100
M5-60 (mm)	19.600	Add Flow / Climate Change (%)	0
Ratio R	0.350	Minimum Backdrop Height (m)	0.200
Maximum Rainfall (mm/hr)	50	Maximum Backdrop Height (m)	1.500
Maximum Time of Concentration (mins)	30	Min Design Depth for Optimisation (m)	1.200
Foul Sewage (l/s/ha)	0.000	Min Vel for Auto Design only (m/s)	1.00
Volumetric Runoff Coeff.	0.750	Min Slope for Optimisation (1:X)	500

Designed with Level Soffits

Time Area Diagram for Storm



Total Area Contributing (ha) = 0.116

Total Pipe Volume (m³) = 0.177

Network Design Table for Storm



1.000	5.000	0.063	79.4	0.116	4.00	0.0	0.600	o	150 Pipe/Conduit	
1.001	5.000	0.063	80.0	0.000	0.00	0.0	0.600	o	150 Pipe/Conduit	

Network Results Table



1.000	50.00	4.07	14.500	0.116	0.0	0.0	0.0	1.13	20.0	15.7
1.001	50.00	4.15	14.437	0.116	0.0	0.0	0.0	1.12	19.9	15.7

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Area Summary for Storm

						
1.000	-	-	100	0.116	0.116	0.116
1.001	-	-	100	0.000	0.000	0.000
				Total	Total	Total
				0.116	0.116	0.116

Simulation Criteria for Storm

Volumetric Runoff Coeff	0.750	Additional Flow - % of Total Flow	0.000
Areal Reduction Factor	1.000	MADD Factor * 10m³/ha Storage	2.000
Hot Start (mins)	0	Inlet Coefficient	0.800
Hot Start Level (mm)	0	Flow per Person per Day (l/per/day)	0.000
Manhole Headloss Coeff (Global)	0.500	Run Time (mins)	60
Foul Sewage per hectare (l/s)	0.000	Output Interval (mins)	1

Number of Input Hydrographs	0	Number of Storage Structures	0
Number of Online Controls	0	Number of Time/Area Diagrams	0
Number of Offline Controls	0	Number of Real Time Controls	0

Synthetic Rainfall Details

Rainfall Model	FSR	Profile Type	Summer
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	19.600	Storm Duration (mins)	30
Ratio R	0.350		

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1 year Return Period Summary of Critical Results by Maximum Level (Rank 1)
for Storm

Simulation Criteria

Areal Reduction Factor	1.000	Additional Flow - % of Total Flow	0.000
Hot Start (mins)	0	MADD Factor * 10m³/ha Storage	2.000
Hot Start Level (mm)	0	Inlet Coefficient	0.800
Manhole Headloss Coeff (Global)	0.500	Flow per Person per Day (l/per/day)	0.000
Foul Sewage per hectare (l/s)	0.000		

Number of Input Hydrographs 0 Number of Storage Structures 0
Number of Online Controls 0 Number of Time/Area Diagrams 0
Number of Offline Controls 0 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model	FSR	Ratio R	0.350
Region England and Wales Cv (Summer)			0.750
M5-60 (mm)	19.500	Cv (Winter)	0.840

Margin for Flood Risk Warning (mm) 0.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

Profile(s) Summer and Winter

Duration(s) (mins)	15, 30, 60, 120, 240, 360, 480, 960, 1440
Return Period(s) (years)	1, 30, 100
Climate Change (%)	0, 0, 0



1.000	1	15 Winter	1	+0%	30/15 Summer	30/15 Summer	14.625
1.001	2	15 Winter	1	+0%	30/15 Summer		14.562



1.000	1	-0.025	0.000	1.00	15.7	OK	6
1.001	2	-0.025	0.000	0.99	15.5	OK	

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30 year Return Period Summary of Critical Results by Maximum Level (Rank 1)
for Storm

Simulation Criteria

Areal Reduction Factor 1.000 Additional Flow - % of Total Flow 0.000
Hot Start (mins) 0 MADD Factor * 10m³/ha Storage 2.000
Hot Start Level (mm) 0 Inlet Coefficient 0.800
Manhole Headloss Coeff (Global) 0.500 Flow per Person per Day (l/per/day) 0.000
Foul Sewage per hectare (l/s) 0.000

Number of Input Hydrographs 0 Number of Storage Structures 0
Number of Online Controls 0 Number of Time/Area Diagrams 0
Number of Offline Controls 0 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model FSR Ratio R 0.350
Region England and Wales Cv (Summer) 0.750
M5-60 (mm) 19.500 Cv (Winter) 0.840

Margin for Flood Risk Warning (mm) 0.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

Profile(s)

Duration(s) (mins) 15, 30, 60, 120, 240, 360, 480, 960, 1440
Return Period(s) (years) 1, 30, 100
Climate Change (%) 0, 0, 0



1.000	1	15 Winter	30	+0%	30/15 Summer	30/15 Summer	15.000
1.001	2	15 Winter	30	+0%	30/15 Summer		14.769



1.000	1	0.350	0.355	1.96	30.8	FLOOD	6
1.001	2	0.173	0.000	1.97	30.8	SURCHARGED	

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100 year Return Period Summary of Critical Results by Maximum Level (Rank 1) for Storm

Simulation Criteria

Areal Reduction Factor 1.000 Additional Flow - % of Total Flow 0.000
Hot Start (mins) 0 MADD Factor * 10m³/ha Storage 2.000
Hot Start Level (mm) 0 Inlet Coefficient 0.800
Manhole Headloss Coeff (Global) 0.500 Flow per Person per Day (l/per/day) 0.000
Foul Sewage per hectare (l/s) 0.000

Number of Input Hydrographs 0 Number of Storage Structures 0
Number of Online Controls 0 Number of Time/Area Diagrams 0
Number of Offline Controls 0 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model FSR Ratio R 0.350
Region England and Wales Cv (Summer) 0.750
M5-60 (mm) 19.500 Cv (Winter) 0.840

Margin for Flood Risk Warning (mm) 0.0 DVD Status OFF
Analysis Timestep Fine Inertia Status OFF
DTS Status ON

Profile(s)

Duration(s) (mins) 15, 30, 60, 120, 240, 360, 480, 960, 1440
Return Period(s) (years) 1, 30, 100
Climate Change (%) 0, 0, 0



1.000	1	15 Winter	100	+0%	30/15 Summer	30/15 Summer	15.003
1.001	2	15 Winter	100	+0%	30/15 Summer		14.769



1.000	1	0.353	2.799	1.96	30.9	FLOOD	6
1.001	2	0.173	0.000	1.97	30.9	SURCHARGED	

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STORM SEWER DESIGN by the Modified Rational Method

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k (mm)	HYD SECT	DIA (mm)	Section Type	Auto Design
1.000	44.051	3.352	13.1	0.010	4.00	0.0	0.600	o	150	Pipe/Conduit	☺
1.001	9.609	0.255	37.8	0.059	0.00	0.0	0.600	o	150	Pipe/Conduit	☺
2.000	16.292	0.163	100.0	0.011	4.00	0.0	0.600	o	150	Pipe/Conduit	☺
2.001	12.447	0.124	100.4	0.012	0.00	0.0	0.600	o	150	Pipe/Conduit	☺
2.002	27.368	0.122	224.3	0.029	0.00	0.0	0.600	o	225	Pipe/Conduit	☺
2.003	14.593	0.065	224.5	0.013	0.00	0.0	0.600	o	225	Pipe/Conduit	☺
2.004	17.190	1.478	11.6	0.004	0.00	0.0	0.600	o	225	Pipe/Conduit	☺
2.005	45.164	0.949	47.6	0.008	0.00	0.0	0.600	o	225	Pipe/Conduit	☺
2.006	37.258	0.154	242.7	0.028	0.00	0.0	0.600	o	300	Pipe/Conduit	☺

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	E I.Area (ha)	E Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
1.000	150.00	4.26	13.716	0.010	0.0	0.0	0.0	2.79	49.4	4.1
1.001	150.00	4.36	10.364	0.069	0.0	0.0	0.0	1.64	29.0	27.9
2.000	150.00	4.27	13.164	0.011	0.0	0.0	0.0	1.01	17.8	4.4
2.001	150.00	4.48	13.001	0.023	0.0	0.0	0.0	1.00	17.7	9.4
2.002	147.82	5.00	12.802	0.052	0.0	0.0	0.0	0.87	34.5	20.8
2.003	145.00	5.28	12.680	0.065	0.0	0.0	0.0	0.87	34.5	25.3
2.004	144.28	5.36	12.615	0.069	0.0	0.0	0.0	3.86	153.4	27.0
2.005	140.57	5.75	11.137	0.077	0.0	0.0	0.0	1.90	75.6	29.5
2.006	135.26	6.37	10.113	0.106	0.0	0.0	0.0	1.00	71.0	38.8

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STORM SEWER DESIGN by the Modified Rational Method

Network Design Table for Storm

PN	Length (m)	Fall (m)	Slope (1:X)	I.Area (ha)	T.E. (mins)	Base Flow (l/s)	k	HYD SECT	DIA (mm)	Section Type	Auto Design
1.002	9.755	0.040	243.9	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	☑
1.003	12.117	0.050	242.3	0.000	0.00	0.0	0.600	o	300	Pipe/Conduit	☑
3.000	20.226	0.202	100.1	0.022	4.00	0.0	0.600	o	150	Pipe/Conduit	☑
3.001	9.380	0.094	99.8	0.015	0.00	0.0	0.600	o	150	Pipe/Conduit	☑
3.002	10.271	0.042	244.5	0.045	0.00	0.0	0.600	o	300	Pipe/Conduit	☑
3.003	7.834	0.592	13.2	0.068	0.00	0.0	0.600	o	300	Pipe/Conduit	☑

Network Results Table

PN	Rain (mm/hr)	T.C. (mins)	US/IL (m)	E I.Area (ha)	E Base Flow (l/s)	Foul (l/s)	Add Flow (l/s)	Vel (m/s)	Cap (l/s)	Flow (l/s)
1.002	133.96	6.53	9.959	0.175	0.0	0.0	0.0	1.00	70.9	63.4
1.003	132.38	6.73	9.919	0.175	0.0	0.0	0.0	1.01	71.1	63.4
3.000	150.00	4.34	13.930	0.022	0.0	0.0	0.0	1.00	17.7	9.1
3.001	150.00	4.49	13.828	0.038	0.0	0.0	0.0	1.01	17.8	15.4
3.002	150.00	4.66	13.584	0.083	0.0	0.0	0.0	1.00	70.8	33.5
3.003	150.00	4.69	13.542	0.151	0.0	0.0	0.0	4.34	307.1	61.2

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Free Flowing Outfall Details for Storm

Outfall Pipe Number	Outfall C. Level Name	I. Level (m)	Min I. Level (m)	D,L (mm)	W (mm)
1.003		10.500	9.869	9.870	0 0

Free Flowing Outfall Details for Storm

Outfall Pipe Number	Outfall C. Level Name	I. Level (m)	Min I. Level (m)	D,L (mm)	W (mm)
3.003	11	14.450	12.950	0.000	1200 0

Simulation Criteria for Storm

Volumetric Runoff Coeff 0.750 Manhole Headloss Coeff (Global) 0.500 Inlet Coefficient 0.800
Areal Reduction Factor 1.000 Foul Sewage per hectare (l/s) 0.000 Flow per Person per Day (l/per/day) 0.000
Hot Start (mins) 0 Additional Flow - % of Total Flow 0.000 Run Time (mins) 60
Hot Start Level (mm) 0 MADD Factor * 10m³/ha Storage 2.000 Output Interval (mins) 1

Number of Input Hydrographs 0 Number of Offline Controls 0 Number of Time/Area Diagrams 0
Number of Online Controls 2 Number of Storage Structures 2 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model	FSR	M5-60 (mm)	19.500	Cv (Summer)	0.750
Return Period (years)	100	Ratio R	0.350	Cv (Winter)	0.840
Region	England and Wales	Profile Type	Summer	Storm Duration (mins)	30

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<u>Online Controls for Storm</u>											
<u>Depth/Flow Relationship Manhole: 1-2, DS/PN: 1.002, Volume (m³): 4.6</u>											
Invert Level (m) 9.959											
Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	0.0000	0.600	0.0000	1.100	0.0000	1.600	0.0000	2.100	0.0000	2.600	0.0000
0.200	0.0000	0.700	0.0000	1.200	0.0000	1.700	0.0000	2.200	0.0000	2.700	0.0000
0.300	0.0000	0.800	0.0000	1.300	0.0000	1.800	0.0000	2.300	0.0000	2.800	0.0000
0.400	0.0000	0.900	0.0000	1.400	0.0000	1.900	0.0000	2.400	0.0000	2.900	0.0000
0.500	0.0000	1.000	0.0000	1.500	0.0000	2.000	0.0000	2.500	0.0000	3.000	0.0000
<u>Depth/Flow Relationship Manhole: 3-3, DS/PN: 3.003, Volume (m³): 1.1</u>											
Invert Level (m) 13.542											
Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	0.0000	0.600	0.0000	1.100	0.0000	1.600	0.0000	2.100	0.0000	2.600	0.0000
0.200	0.0000	0.700	0.0000	1.200	0.0000	1.700	0.0000	2.200	0.0000	2.700	0.0000
0.300	0.0000	0.800	0.0000	1.300	0.0000	1.800	0.0000	2.300	0.0000	2.800	0.0000
0.400	0.0000	0.900	0.0000	1.400	0.0000	1.900	0.0000	2.400	0.0000	2.900	0.0000
0.500	0.0000	1.000	0.0000	1.500	0.0000	2.000	0.0000	2.500	0.0000	3.000	0.0000
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Storage Structures for Storm

Cellular Storage Manhole: 1-2, DS/PN: 1.002

Invert Level (m) 9.959 Safety Factor 2.0

Infiltration Coefficient Base (m/hr) 0.03600 Porosity 0.95

Infiltration Coefficient Side (m/hr) 0.03600

Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)	Depth (m)	Area (m ²)	Inf. Area (m ²)
0.000	170.0	170.0	0.800	170.0	213.2	0.900	0.0	213.2

Porous Car Park Manhole: 3-3, DS/PN: 3.003

Infiltration Coefficient Base (m/hr) 0.03600

Width (m) 38.8

Membrane Percolation (mm/hr) 1000

Length (m) 38.8

Max Percolation (l/s) 418.2

Slope (1:X) 0.0

Safety Factor 2.0

Depression Storage (mm) 5

Porosity 0.30

Evaporation (mm/day) 3

Invert Level (m) 13.631

Cap Volume Depth (m) 0.300

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Summary of Critical Results by Maximum Level (Rank 1) for Storm

Simulation Criteria

Areal Reduction Factor 1.000	Manhole Headloss Coeff (Global) 0.500	MADD Factor * 10m³/ha Storage 2.000
Hot Start (mins) 0	Foul Sewage per hectare (l/s) 0.000	Inlet Coefficient 0.800
Hot Start Level (mm) 0	Additional Flow - % of Total Flow 0.000	Flow per Person per Day (l/per/day) 0.000

Number of Input Hydrographs 0 Number of Offline Controls 0 Number of Time/Area Diagrams 0
Number of Online Controls 2 Number of Storage Structures 2 Number of Real Time Controls 0

Synthetic Rainfall Details

Rainfall Model	FSR M5-60 (mm)	19.500 Cv (Winter) 0.840
Return Period (years)	100	Ratio R 0.350
	Region England and Wales Cv (Summer)	0.750

Margin for Flood Risk Warning (mm) 300.0
Analysis Timestep 2.5 Second Increment (Extended)
DTS Status ON
DVD Status ON
Inertia Status ON

Profile(s) Summer and Winter
Duration(s) (mins) 15, 30, 60, 120, 240, 360, 480, 960, 1440
Sensitivity flows(s) (%) 0, +40

US/MR		US	Water Surcharged Flooded								
PN	Name	Label	Event	Storm Rank	US/CL (m)	Level (m)	Depth (m)	Volume (m³)	Flow / Overflow Cap.	Infil. Flow (l/s)	Maximum Vol (m³)
1.000	1-0		15 minute 100 year Winter Q+40%	1	15.052	13.752	-0.114	0.000	0.13		0.009

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<u>Summary of Critical Results by Maximum Level (Rank 1) for Storm</u>		

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Summary of Critical Results by Maximum Level (Rank 1) for Storm

PN	US/MH Name Label	Event	Storm Rank	US/CL (m)	Water Surcharged Flooded			Flow / Overflow (l/s)	Infil. Flow (l/s)	Maximum Vol (m³)
					Level (m)	Depth (m)	Volume (m³)			
1.001	1-1	15 minute 100 year Winter Q+40%	1	11.700	10.938	-0.424	0.000	1.60		0.278
2.000	2-0	15 minute 100 year Winter Q+40%	1	14.500	13.230	-0.084	0.000	0.41		0.017
2.001	2-1	15 minute 100 year Winter Q+40%	1	14.500	13.129	-0.022	0.000	0.85		0.227
2.002	2-2	15 minute 100 year Winter Q+40%	1	14.500	13.043	0.016	0.000	0.94		0.191
2.003	2-3	15 minute 100 year Winter Q+40%	1	14.500	12.931	0.026	0.000	1.23		0.315
2.004	2-4	15 minute 100 year Winter Q+40%	1	14.400	12.698	-0.142	0.000	0.29		0.133
2.005	2-5	15 minute 100 year Winter Q+40%	1	12.563	11.264	-0.098	0.000	0.60		0.153
2.006	2-6	960 minute 100 year Winter Q+40%	1	11.421	10.664	0.251	0.000	0.07		0.820
1.002	1-2	960 minute 100 year Winter Q+40%	1	11.600	10.664	0.404	0.000	0.00	1.0	117.305
1.003	1-3	480 minute 100 year Winter Q+0%	1	11.059	9.919	-0.300	0.000	0.00		0.000
3.000	3-0	15 minute 100 year Winter Q+40%	1	15.380	14.221	0.041	0.000	0.81		0.053
3.001	3-1	15 minute 100 year Winter Q+40%	1	15.325	14.082	0.164	0.000	1.44		0.345
3.002	3-2	15 minute 100 year Winter Q+40%	1	15.295	13.808	-0.076	0.000	0.89		0.091
3.003	3-3	120 minute 100 year Winter Q+40%	1	15.150	13.733	-0.109	0.000	0.00	7.5	46.421

PN	US/MH Name	Discharge Vol (m³)	Flow (l/s)	Status	Pipe
1.001	1-1	18.567	41.2	SURCHARGED	
2.000	2-0	2.924	6.7	OK	
2.001	2-1	6.250	13.7	OK	
2.002	2-2	14.005	30.0	SURCHARGED	
2.003	2-3	17.428	37.3	SURCHARGED	
2.004	2-4	18.634	39.7	OK	

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<u>Summary of Critical Results by Maximum Level (Rank 1) for Storm</u>				
			Pipe	
		US/MH Discharge	Flow	
FN	Name	Vol (m³)	(l/s)	Status
2.005	2-5	20.931	43.6	OK
2.006	2-6	101.045	4.4	SURCHARGED
1.002	1-2	0.000	0.0	SURCHARGED
1.003	1-3	0.000	0.0	OK
3.000	3-0	6.074	13.5	SURCHARGED
3.001	3-1	10.268	22.3	SURCHARGED
3.002	3-2	22.224	49.7	OK
3.003	3-3	0.000	0.0	OK
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Appendix 4 – Proposed Surface Water Drainage Strategy Layout

