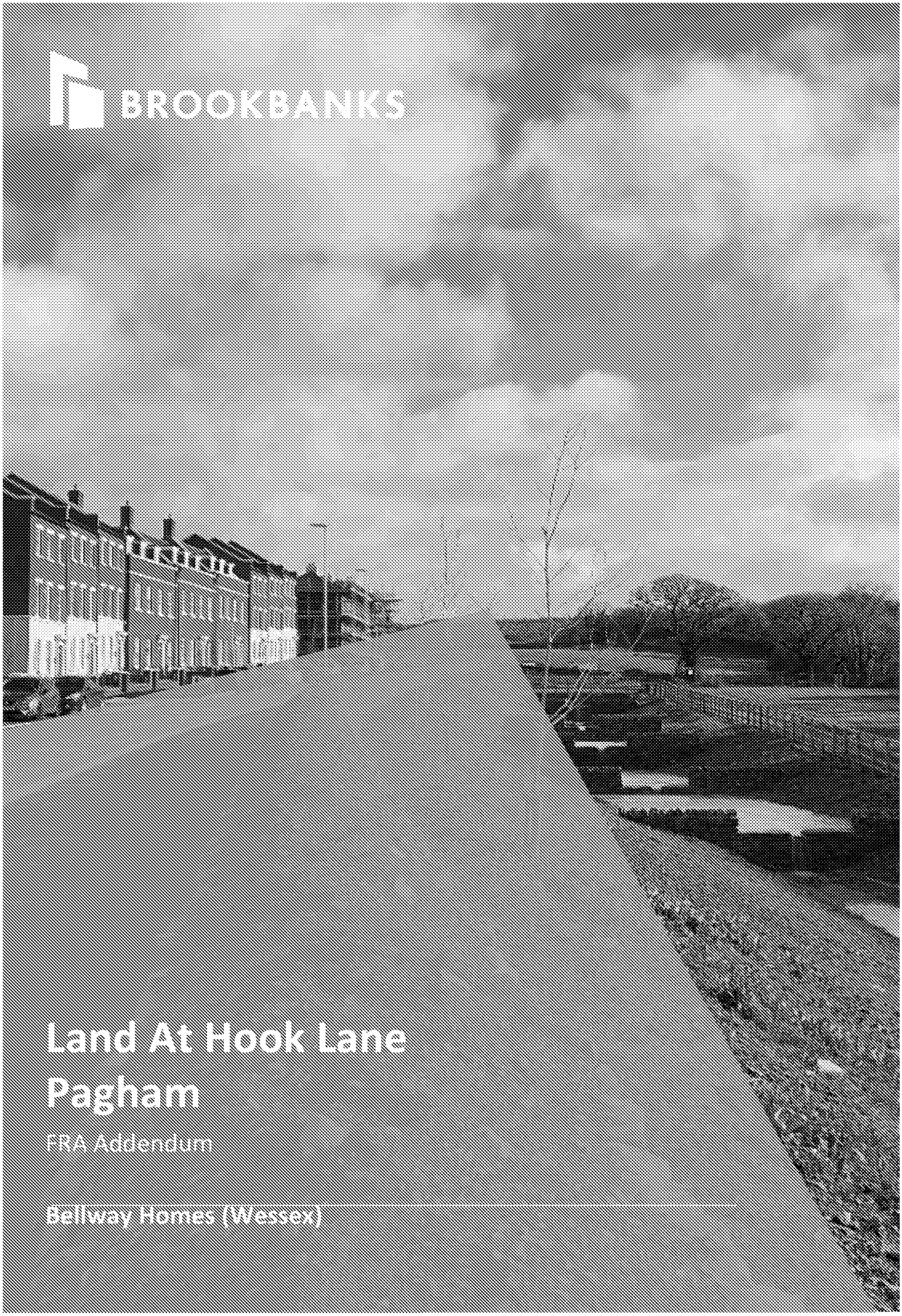
BROOKBANKS



Land At Hook Lane Pagham

FRA Addendum

Bellway Homes (Wessex)

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Document Control Sheet

Document Title	FRA Addendum
Document Ref	DR01
Project Name	Hook Lane Pagham
Project Number	10461
Client	Bellway Homes (Wessex)

Document Status

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Appendices

Appendix A– GEG - Phase 1 Review and Phase 2 Geo-Environmental Assessment
Appendix B– Drainage Strategy and Supporting Calculations

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1 Introduction

1.1 Brookbanks have been appointed to prepare an addendum to the previously approved Flood Risk Assessment (FRA)to support a reserved matters planning application for development at Hook Lane Pagham

1.2 The site already benefits from an Outline Planning Consent which covers the principles of the development and associated infrastructure within the site boundary. Whilst approved in principle as part of the outline consent (**P/30/19/OUT**) this report provides supporting details to demonstrate that the development remains acceptable from a flood risk and drainage viewpoint and accords with the previously approved Flood Risk Assessment following further detailed design.

1.3 This report summarises the findings of the study and specifically addresses the following issues in the context of the current legislative regime:

- Flooding risk
- Surface water drainage
- Foul water drainage

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2 Background Information

2.1 The site is located in Pahgam, near Bognor Regis in West Sussex. It is bounded by Hook Lane and Pagham Road and covers an area of approximately 17.5ha. The site is currently undeveloped and is not thought to have been historically subject to any significant built development. The site is currently used for agriculture with tree lines and hedgerows marking the site boundaries.

2.2 WSP have prepared a Flood Risk Assessment report dated January 2017 ref 4147 FRA Rev4 (hereafter referred to as the approved FRA) with full details in relation to the site history, hydrology and hydrogeology. The FRA has been submitted and approved as part of the outline planning consent for the site. Whilst the site lies within the consented application, this report provide further justification as to the appropriateness of the development in relation to Flood Risk and water quality.

2.3 The proposed development comprises up to 300 new homes, a care home and primary school along with the associated infrastructure. The current masterplan is shown below.



Figure 2-1: – Illustrative Masterplan – Thrive Architects Ref OSKL-01

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2.4 The reserved matters submission is pursuant to outline planning permission, therefore the addendum has been prepared to inform the submission in relation to the relevant drainage conditions namely:

2.5 *Condition 10- Development shall not commence, other than works of site survey and investigation, until full details of the proposed surface water drainage scheme have been submitted to and approved in writing by the Local Planning Authority. The design should follow the hierarchy of preference for different types of surface water drainage disposal systems as set out in Approved Document H of the Building Regulations, and the recommendations of the SuDS Manual produced by CIRIA. Winter groundwater monitoring to establish highest annual ground water levels and winter Percolation testing to BRE 365, or similar approved, will be required to support the design of any Infiltration drainage. No building shall be occupied until the complete surface water drainage system serving the property has been implemented in accordance with the agreed details and the details so agreed shall be maintained in good working order in perpetuity.*

2.6 *Condition 11- The development shall not proceed until details have been submitted to and approved in writing by the Local Planning Authority for any proposals: to discharge flows to watercourses; or for the culverting, diversion, infilling or obstruction of any watercourse on or adjacent to the site. Any discharge to a watercourse must be at a rate no greater than the pre-development run-off values. No construction is permitted, which will restrict current and future land owners from undertaking their riparian maintenance responsibilities in respect to any watercourse or culvert on or adjacent to the site.*

2.7 *Condition 12 - Development shall not commence until full details of the maintenance and management of the surface water drainage system is set out in a site-specific maintenance manual and submitted to, and approved in writing, by the Local Planning Authority. The manual is to include details of financial management and arrangements for the replacement of major components at the end of the manufacturer's recommended design life. Upon completed construction of the surface water drainage system, the owner or management company shall strictly adhere to and implement the recommendations contained within the manual.*

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3 Ground Conditions

3.1 The permeability of the site has been considered. The Environment Agency (EA) Groundwater Vulnerability Map Sheet 50 (1:100,000)indicates that the vast majority of site to be underlain by strata is unnderlain by a secondary aquifer. This aquifer has been characterised as a 'Secondary A' aquifer. That is permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.'

3.2 The online Environment Agency Groundwater map (Bedrock Designation) indicates that the site comprises stratum that is considered 'Unproductive Strata'. That is, impermeable layers incapable of supporting water supplies.

3.3 Site investigations completed by WSP at the outline stage indicates the site geology consists of River Terrace Deposits, supporting the information provided by the BGS superficial geology map.

3.4 Testing to BRE Digest 365 was conducted on site. Testing indicated that the underlying geology was relatively impermeable. A Soakaway Report was included as an appendix in the consented FRA and states *"Infiltration rates could not be calculated in accordance with BRE guidance for any of the test locations due to slow drainage rates and the absence of 75% effective depth soakage within the timeframe of the tests." As such, it is unfeasible to drain the site via infiltration.*

3.5 GEG have undertaken a Phase I Review and Phase II Geo-Environmental Assessment and the findings are presented in the Report Ref GEG -19-23 dated January 2020. The report is presented in Appendix B.

3.6 Intrusive investigations were undertaken in October 2019. The investigations confirm the findings of the WSP report as it was not possible to calculate soil infiltration rates due to the absence of significant infiltration and therefore infiltration is discounted for this site.

3.7 The report also confirms the presence of shallow groundwater and this is discussed further in Section 4.

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4 Flood Risk

4.1 As part of the outline application for the site, the approved FRA assessed the risk of flooding from the Hook Lane site concluding that it is an appropriate location for development of this nature.

4.2 The paragraphs below outline the site flood risk mechanisms specifically in relation to the proposed development, having regard to the findings of the approved FRA

Historic Flooding

4.3 The approved FRA identified that there are a number of historic flood events that have occurred in the immediate vicinity of the site. Details are included in the SFRA published by Arun District Council in August 2016. Additionally anecdotal evidence at public consultation suggested flooding to Hook Lane. Arun Distrrict Council have also provided details of flooding at Sefter Cottage to the west of site. The incident was documented in Section 19 Flood Incident report which affected most of the county in June 2012 following a 1 in 212 year return period event.

Fluvial Flooding

4.4 The approved FRA refers to the SFRA where it mentions the watercourse Pagham Rife that is in close proximity to the west of the site. The SFRA does not discuss flood impact zones but does reference flood defences present towards Pagham Harbour. The defences in place along the western part of Pagham Village include embankments and raised walls with condition grading recorded as good and fair.

4.5 Fluvial Flood Zones were produced as part of the SFRA and show the site to be located in Flood Zone with regard to fluvial flooding.

4.6 The mapping shows the proposed Hook Lane development to lie within Flood Zone 1, being an area of Low Probability of flooding, outside both the 1 in 100 (1% AEP) and 1 in 1,000 (0.1% AEP) year flood events. The current Environment Agency (EA)Flood Zone Map is shown in Figure 4-1

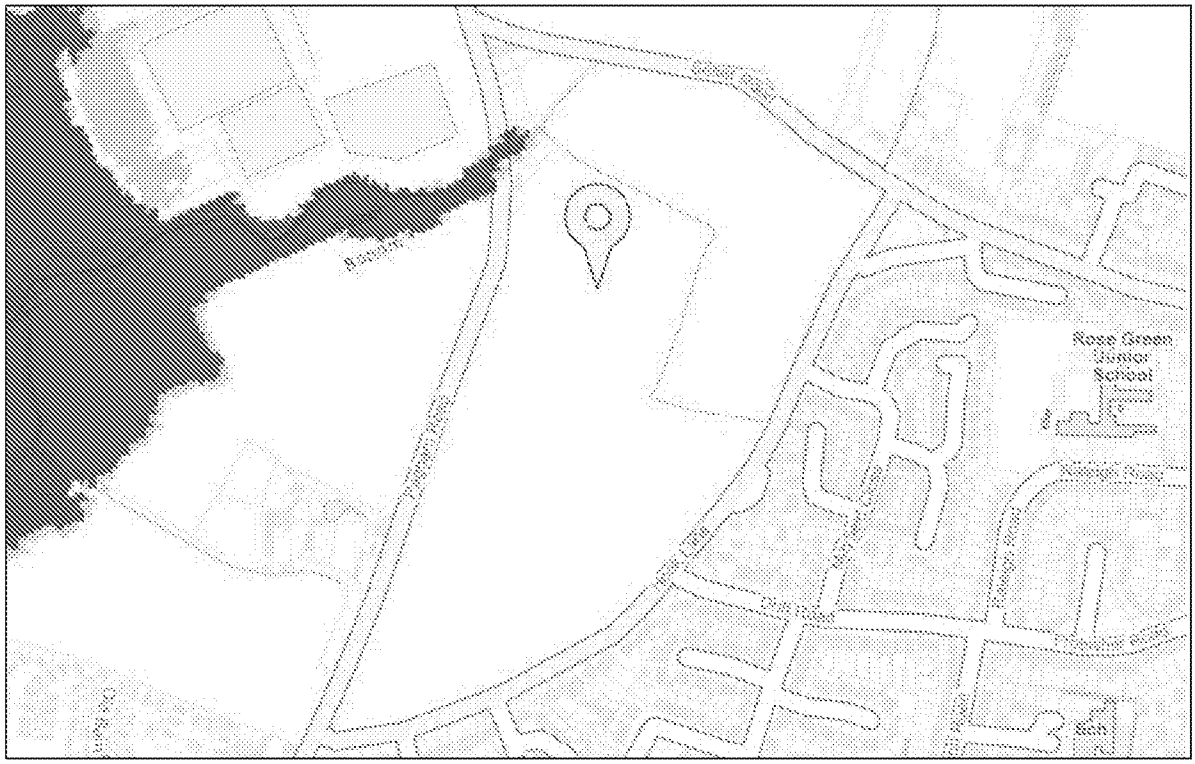


Figure 4-1: – Flood Map for Planning from Environment Agency mapping database

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On Site Drainage Ditch

4.7 Figure 4-1 illustrates that there is an ordinary watercourse or ditch that crosses the site in an east to west direction. The watercourse discharges to Pagham Rife. The FRA assessment of the EA LIDAR data calculated the catchment watershed to be approx. 67ha.

4.8 Topographical survey data shows the ditch to be approximately 1.0 to 2.0m with side slopes of 1 in 1 and 1 in 2. At the western end flow is controlled by a 450mm diameter culvert, estimated to have a maximum capacity of 164l/s.

4.9 The approved FRA has calculated the greenfield run off rate as 197l/s from the site at 1 in 100 year event and the post development flows will be restricted to Q_{bar} at approximately 18.5l/s.

4.10 The proposals included widening of the on site drainage ditch and providing a blue green corridor to provide additional flood risk protection along with bio-diverse and ecological benefits.

4.11 Fluvial flood risk does not pose a risk to the proposed development and alongside this the proposed development provides some flood risk protection measures to downstream properties in reduced runoff rates.

Tidal Flooding

4.12 The risk of tidal flooding is shown above in Figure 3a and was also assessed as part of the 2016 SFRA. The site is located in Flood Zone 1 and is therefore deemed to have a less that 0.1% annual probability of tidal flooding.

4.13 A sequential approach has been employed in the development of the masterplan, locating areas away from the most risk of flooding. As such tidal flooding is not considered a significant risk to built development at this location and the overall flood risk is low.

Groundwater Flooding

4.14 The SFRA shows the site to be at medium to high risk of groundwater flooding. EA mapping show that there are no Source Protection Zones within 1.5km of the site. Infiltration from the basins will not pose a risk to groundwater.

4.15 It is reported in the approved FRA that at public consultation residents raised concerns with the proposed development due to shallow groundwater. Groundwater levels were monitored and the findings were presented by WSP in report ref 7001417-R02 –Groundwater Monitoring Report. The findings of the report were as follows:

- Results indicated a presence of a sub-artesian groundwater body with depths of groundwater typically less than 1.0m below ground level.
- Risk of flooding from groundwater considered medium
- Minor earthworks recommended to provide surface water flow paths and development areas to be raised.
- Increase in impermeable area will decrease responsiveness of groundwater and reduce flood risk
- Deep drainage features to be lined to prevent ground water ingress

4.16 Further site investigation works have been undertaken by GEG with groundwater monitoring between November to 2019 to January 2020 . The findings are in report attached as appendix A and reported that groundwater was encountered at depths of 1.2 to 3.0m

4.17 Given the mitigation measure to be employed on site the risk of groundwater flooding is considered low,

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Surface Water Flooding

4.18 The EA's Surface Water Flood Mapping identifies a number of areas that are at high risk from surface water flooding as illustrated in Figure 4-2 below. The mapping shows there is low to medium risk of flooding from the ditches and a high risk area to the south that corresponds with a low area on the topographical survey.

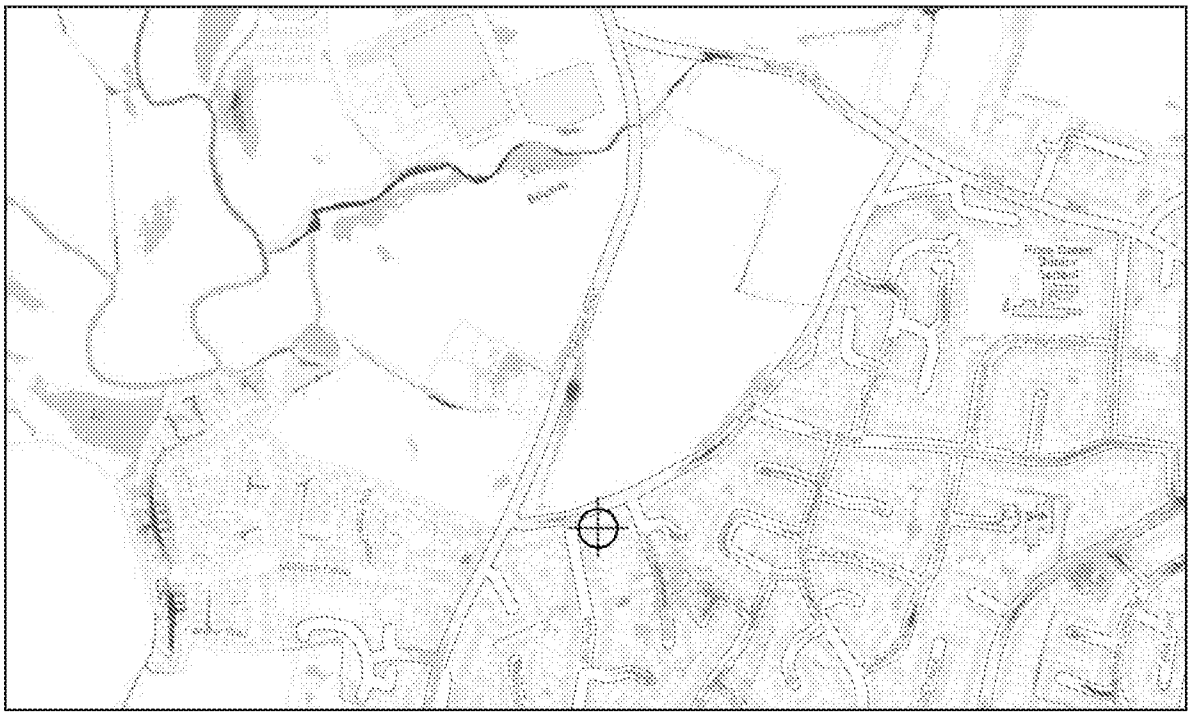


Figure 4-2: – Surface Water Flood Map from Environment Agency mapping database

4.19 A site visit was undertaken as part of the approved FRA and found a gully grate in the south west corner of the site likely to allow runoff to drain beneath Paghman Road. Public consultations raised concern over surface water flooding in the area with anecdotal evidence suggesting highway flooding on a "semi-regular" basis.

4.20 A review of the existing highway cross sections and proposed development including the recommended earthworks found that the proposed development will drain to the west and will not exacerbate the flooding in Hook Lane .

4.21 The approved FRA concluded Given that the highest risk areas are in the low points of the site where SuDS drainage is to be situated, the sequential approach to masterplan development and the minor earthworks required to ensure catchments fall towards basins, the risk of flooding from surface water sources will be low.

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Exceedance Flows

4.22 The drainage strategy in Section 5 will discuss the exceedance flows in further detail as recommended in the approved FRA. A principal exceedance strategy was presented in WSP Drawing Ref 4147-D-02 presented in Figure 4-3 below

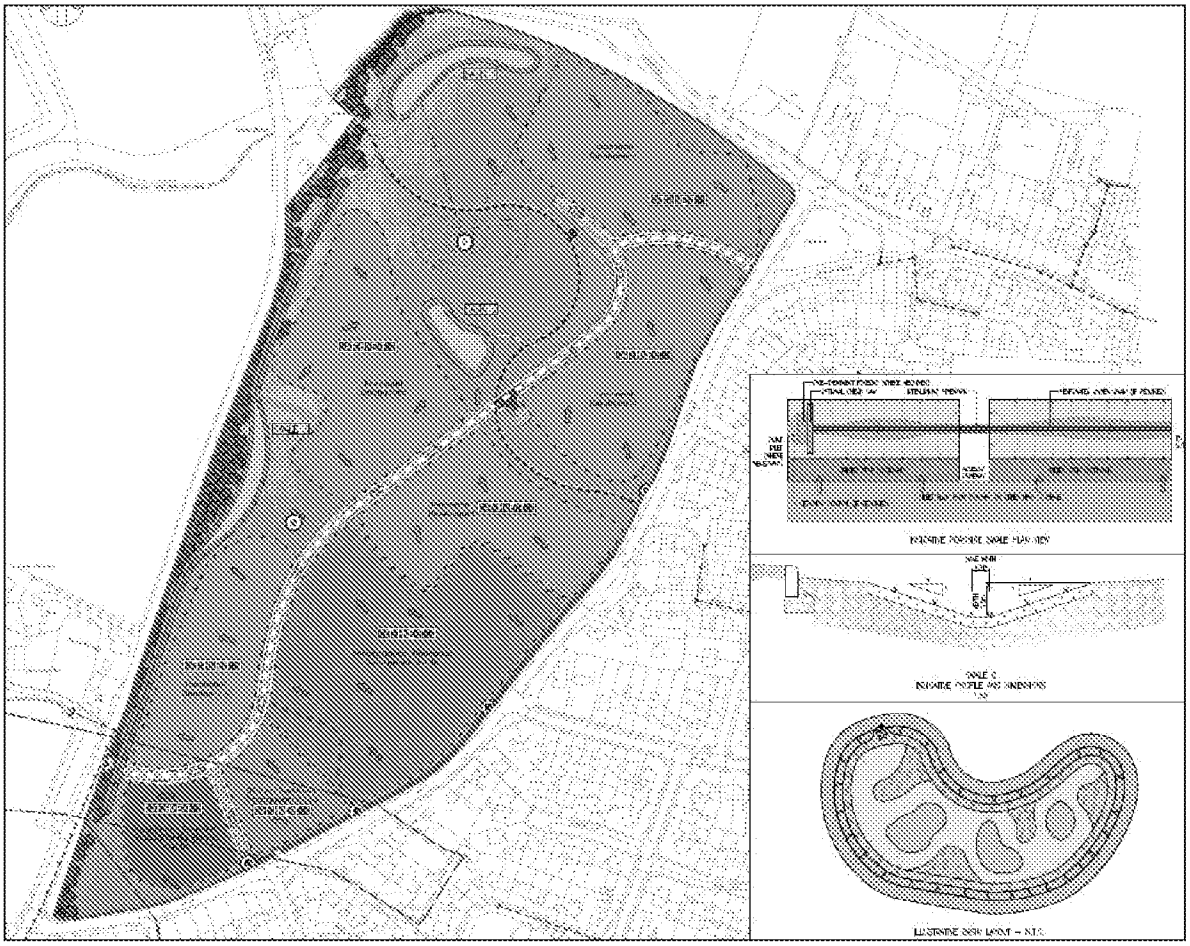


Figure 4-3: Extract from illustrative drainage strategy WSP drawing ref 4147-D-02

4.23 The risk from exceedance flows is considered low.

Flooding from other sources

4.24 The approved FRA found the risk of flooding from other sources including reservoirs, canals and sewers to be low or discounted.

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5 Surface Water Drainage Strategy

5.1 The principles of how the site is to be drained is set out in the approved FRA and therefore the drainage proposals described below follow these principles.

- Mimic the existing drainage regime of the site.
- Maintain flow rates of volumes discharged from the site through the use of Sustainable Drainage Systems (SuDS)
- Provide water quality, landscape , ecology and biodiversity benefits through the provision of SuDS
- The use of infiltration to discharge surface water has been discounted therefore following current PPG guidance the next appropriate receptor for the runoff from the development will be to the existing watercourse.
- Restrict discharge rates to Q_{bar} for up to and including the 1 in 100 year storm event plus 40% climate change.
- Design the onsite drainage network to adoptable standards.
- Ensure the proposed SuDS system has capacity to accommodate urban creep.
- Consider source control measures through detailed design.
- Management of extreme flood risk events through the design of finished floor levels set above adjacent roads and open spaces.
- Ensure safe access and egress will be available up to and included the 1 in 100 year storm event plus 40% climate change.

5.2 The findings of GEG in their updated Site Investigation works confirm that infiltration is not viable for the site refer to Appendix A.

5.3 The illustrative drainage strategy presented in the approved FRA and the extract shown in Figure 4-3 indicates that the site will discharge to the existing watercourse via a series of basins and swales.

5.4 The drainage strategy has been designed in accordance with the approved FRA and is presented in drawings contained within Appendix B.

5.5 The proposed development layout has been utilised to produce a drainage network based on the contributing areas to each SuDS feature. All surface water sewers will be designed as per the requirements of Southern Water and the Design and Construction Guidance (DCG) published in April 2020.

5.6 Discussions have taken place with Arun District Council (ADC) as the approving LLFA in October 2020 to further inform the Drainage Strategy and agree the details presented in this report.

5.7 ADC have suggested that south west corner of the site should outfall to the land drainage system under Hook Lane just south of Field View. A review of the proposed layout and levels suggests that this is not feasible and therefore the strategy complies with the outfall arrangement set out in the approved FRA i.e. existing watercourse. However, in order to further reduce the risk of flooding in an exceedance event the design includes a high level overflow pipe set above the 1 in 100 year water level outfalling to this existing land drainage outfall to the south of the site.

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5.8 An assessment of the impermeable area has been undertaken based on the current masterplan. An assumed impermeable area of 60% has been used to calculate the discharge rates and required storage through the use of MicroDrainage software. The 60% impermeable area includes an allowance for urban creep. Discharge rates will be restricted to Q_{bar} as set out in the approved FRA. Storage is provided for up to and including the 100 year storm event with an allowance of 40% climate change. Calculations for the SuDS basins can be found within Appendix C and are summarised in the table below:

Catchment Area Ref	Development Area (ha)	Impermeable Area (assumed 60%) (ha)	Storage (m^3) 1 in 100 yr +40% event	Discharge Rate Q_{bar} (l/s)
Catchment 1	4.84	3.13 (incl. care home)	2,460	10.8
Catchment 2	2.31	1.39	1,089	5
Catchment 3	3	1.8	1,423	6.3

Table 4-1: Catchment Summary

5.9 As suggested in the approved FRA there is an opportunity to naturalise the watercourse through a blue green corridor to the north of Catchment 1 and 2. Details of the naturalised watercourse are presented in in Appendix B. The blue green corridor will provide further opportunity to enhance the water quality, landscape , ecology and biodiversity benefits.

5.10 SuDS features and the watercourse diversion will be designed with a maintenance offset of 3m. Root protection areas have been considered and where possible a 3m offset is respected, however there may be a requirement to provide root barriers where this is not achievable.

5.11 The swales have been designed with a 1 in 4 side slope where space allows. A bagwork retaining system has been proposed along the boundary of the western swale due to the space constraints.

5.12 Culvert crossings are provided to accommodate the footway/cycleway network. Through discussion with ADC it is agreed the 600mm diameter pipes are acceptable. The crossing will require Land Drainage Consent.

5.13 Consideration will be given to tree planting and matured root zones where in close proximity to existing culverts.

5.14 Due to the shallow groundwater encountered on site consideration will be given to lining the SuDS features to prevent groundwater ingress.

5.15 The likely exceedance routes have been assessed and have been transposed onto drawing ref 10461-DR-001 included in Appendix B

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6 Foul Drainage

6.1 The approved FRA reported that there were no concerns raised by Southern Water to the proposal to discharge to the Pagham Sewage Treatment works. However reinforcement works are required to the 150m length of 150m diameter sewer running parallel to existing sewers to provide additional capacity.

6.2 It is proposed that foul water flows generated by the Hook Lane Site will be conveyed by a traditional gravity sewer network. Where gravity flows cannot be achieved the flows will be pumped. The foul flows will outfall to the agreed point of connection to the south east of the site.

6.3 The drainage strategy is presented in drawings within Appendix B

6.4 The foul network will be offered for adoption under a S104 agreement with Southern Water.

6.5 Existing pump mains crossing the site to the south will be diverted to suit the development under a S185 agreement with Southern Water.

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7 Water Quality

7.1 Impermeable surfaces collect pollutants from a wide variety of sources including cleaning activities, wear from car tyres, vehicle oil and exhaust leaks and general atmospheric deposition. The implementation of SuDS in development drainage provides a significant benefit in removal of pollutant from development run-off.

7.2 The SuDS Manual C753 describes a 'Simple Index Approach' for assessing the pollution risk of surface run-off to the receiving environment using indices for likely pollution levels for different land uses and SUDS performance capabilities. To deliver adequate treatment SuDS components will be selected to ensure the pollution hazards are effectively treated.

7.3 The conceptual drainage proposals have been developed in a manner that will allow the site wide system to be designed to encourage passive treatment of discharged flows and to improve the water quality by removing the low level silts, oils and metals associated with urban run-off. The design of the drainage system accords with the expectations of SuDS systems and with the approved FRA and will include a number of elements within the drainage train. Final design will provide for appropriate geometry and planting to seek maximise this benefit. Elements of the system may include any source control within development parcels, the collection and deposition of silt through the design of the highway gullies and sewer network system (as is normally and effectively the case within SuDS systems). Planting within the basins ahead of the basin inlet headwalls will also provide for a further level of water quality control. The RM approval also provides for reed beds to be introduced as part of the water quality management system in each basin. As for the detention features themselves the provision of open channel outfalls to the ordinary watercourse receptors provide a further measure to assist in managing water quality.

7.4 The SuDS storm water management features to be implemented will be designed to enhance the biodiversity and landscape character of the site, while also providing amenity space and acting as a functional feature to control storm discharges from the site and improve water quality.

7.5 Collectively the design of the overall drainage system will ensure a broadly based approach to enhancing water quality prior to discharge consistent with the approved FRA.

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8 Maintenance and Management Arrangements

Sewer Network

8.1 At the time of writing it is the intention to offer surface and foul water sewers to Southern Water for adoption under a Section 104 agreement (Water Industry Act 1991). Once complete, Southern Water will be responsible for maintaining these sewer networks and ensuring their continued operation.

SuDS

8.2 In line with the latest DCG the SuDS features will be adopted and maintained by Southern Water.

8.3 A recommended maintenance schedule for the swales is set out below in accordance with SuDS Manual C753.

Maintenance Schedule	Required Action	Typical Frequency
Regular Maintenance	Remove litter and debris	Monthly or as required
	Cut grass – to retain grass height within specified design range	Monthly or as required
	Manage other vegetation and remove nuisance plants	Monthly at the start and then as required.
	Inspect inlets, outlets and overlows for blockages, and clear if required	Monthly
	Inspect vegetation coverage	Monthly for 6 months, quarterly for 2 years, then half yearly
	Inspect inlets and facility surface for silt accumulation, establish appropriate silt removal frequencies	Half Yearly
Occasional Maintenance	Reseed areas of poor vegetation growth, alter plant types to better suit conditions, if required	As required or if bare soil is exposed over 10% or more of the swale treatment area
Remedial Actions	Repair erosion or other damage by re-turfing or reseeding	As required
	Relevel uneven surfaces and reinstate design levels	
	Scarify and spike topsoil layer to improve infiltration performance, break up silt deposits and prevent compaction of the soil surface	
	Remove build-up of sediment on upstream gravel trench, low spreader or at top of filter strip	

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	Remove and dispose of oils or petrol residues using safe standard practices	

Table 8-1: Swale Maintenance Schedule

8.1 A recommended maintenance schedule for the basins is set out below in accordance with SuDS Manual C753.

Maintenance Schedule	Required Action	Typical Frequency
Regular Maintenance	Remove litter and debris	Monthly or as required
	Cut grass – for spillways and access routes	Monthly or as required
	Cut grass – meadow grass in and around basin	Half yearly (spring before nesting season, and autumn)
	Manage other vegetation and remove nuisance plants	Monthly at the start and then as required.
	Inspect inlets, outlets and overflows for blockages, and clear if required	Monthly
	Inspect banksides, structures, pipework etc for signs of physical damage	Monthly
	Inspect inlets and facility surface for silt accumulation. Establish appropriate silt removal frequencies.	Monthly or when required
	Check flow controls and penstocks	Annually
	Tidy all dead growth before start of growing season	Annually
	Remove sediment from inlets,outlets and forebay	Annually
Occasional Maintenance	Reseed areas of poor vegetation growth, alter plant types to better suit conditions, if required	As required
	Prune and trim trees and remove cuttings	Every 2 years or as required
	Remove sediment from inlets, outlets, forebay and main basin when required	Every 5 years or as required
Remedial Actions	Repair erosion or other damage by re-turfing or reseeding	As required
	Realignment of rip rap	
	Repair inlets, outlets and overflows	

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	Remove build-up of sediment on upstream gravel trench, low spreader or at top of filter strip	

Table 8-2: Basin Maintenance Schedule

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9 Summary

9.1 This report has been prepared as an addendum to the approved FRA. The risk of flooding has been assessed and is found to be low in accordance with current guidance and the approved FRA.

9.2 Updated Site investigation works have been undertaken and the findings have been presented in Appendix A.

9.3 The drainage strategy accords with the approved FRA and is presented in drawing 10461-DR-001 attached as Appendix B.

9.4 A surface water drainage strategy has been designed to restrict the discharge rate to Qbar and storage has been provided via a series of SuDS features designed to enhance water quality and accommodate the 1 in 100 year storm event plus allowance for 40% climate change.

9.5 The existing ditch that flows through the site will be naturalised within a blue green corridor to enhance the ecology, biodiversity and landscape of the site.

9.6 A suggested adoption and maintenance schedule has been prepared in accordance with CIRIA SuDS Manual C753

9.7 Foul water flows will be conveyed via gravity and pumping to the agreed outfall

9.8 Safe access and egress will be available to and from the site for events up to and including the 1in 100 year plus 40% climate change rainfall events.

9.9 For all modelled events, risk of flooding is shown to be negligible.

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10 Limitations

10.1 The conclusions and recommendations highlighted above are limited to the general availability of background information and the planned usage of the site.

10.2 Third party information has been used in the preparation of this report, which Brookbanks Consulting Ltd, by necessity assumes is correct at the time of writing. While all reasonable checks have been made on data sources and the accuracy of data, Brookbanks Consulting Ltd accepts no liability for same.

10.3 The benefits of this report are provided to Bellway Homes for the proposed development of land at Hook Lane.

10.4 Brookbanks Consulting Ltd excludes third party rights for the information contained in the report

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Appendix A– GEG - Phase 1 Review and Phase 2 Geo-Environmental Assessment

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[redacted]

PHASE I REVIEW & PHASE II GEO-ENVIRONMENTAL ASSESSMENT



LAND WEST OF HOOK LANE
PAGHAM
PO21 3PD

DECEMBER 2019

Prepared for:

Hallam Land Management

Brookbanks Consulting

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REPORT TITLE: PHASE I REVIEW & PHASE II GEO-ENVIRONMENTAL ASSESSMENT

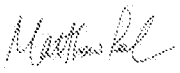
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West Sussex
PO21 3PD

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EXECUTIVE SUMMARY

Current Site Status

The site is located in Pagham, near Bognor Regis, in West Sussex, at the approximate National Grid Reference 489560E, 99180N. It lies on the western side of Hook Lane and east of Pagham Road and covers an area of approximately 17.5 hectares.

The site comprised 2 No. agricultural fields (south western and north eastern) with a westward-flowing drain trending in an east-west orientation along the internal hedged boundary between the fields. A second smaller section of drain was present on the north eastern site boundary.

Geology, Hydrogeology, Hydrology & Landfills

The solid geology beneath the site comprises the London Clay Formation of the Palaeogene period (Unproductive Strata). The solid geology is conjectured to be overlain by superficial deposits of River Terrace Deposits (a Secondary A Aquifer) across the majority of the site, with the north westernmost corner conjectured to be overlain by Raised Beach Deposits 1 (a Secondary Undifferentiated Aquifer).

The site does not lie within a currently defined Groundwater Source Protection Zone (GWSPZ).

The nearest surface water feature is a drain on site flowing westwards towards the Pagham Rife 478m west of the site. A second smaller section of drain was present on the north eastern site boundary. A small pond was present 70m west of the site, as well as 2 No. reservoirs and a pond 190m north west.

There is a record of 1 No. historical landfill site within 250m of the site located 40m north west.

Flooding

The site lies within Flood Zone 1, and hence has a low probability of flooding. However, the land adjacent to the north west of the site is located within Flood Zone 3, with the smallest portion of Flood Zone 2 potentially overlapping the north westernmost tip of the northern site section.

Site History

According to the historical maps provided within the Desk Study, by 1880 the site comprised 2 No. agricultural fields in its current configuration. By 1976, a 'Drain' was identified along the internal field boundary. A second smaller section of 'Drain' was denoted along the north eastern site boundary in 2006. No further significant changes were identified.

Intrusive Investigations

The intrusive investigation was undertaken from 22nd to 25th October 2019 and comprised window sample boreholes, machine-excavated trial pitting, infiltration testing and in-situ CBR testing.

Ground Conditions

Typically soft to firm CLAY topsoil was encountered across the site to depths of 0.30m to 0.50m.

Raised Beach Deposits were encountered underlying the topsoil locally in 2 No. exploratory holes in the north western corner of the site to depths

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of 0.70m and 0.90m respectively. This strata comprised horizons of variably sandy/gravelly soft to firm CLAY and loose to medium dense GRAVEL.

River Terrace Deposits (RTD) were encountered underlying the topsoil to depths ranging from 1.60m to 4.30m across the majority of the site, with the exception of the north westernmost corner. These deposits were typically found to be in excess of 3.00m in thickness across the central and north eastern sections of the site, becoming thinner towards the south western (1.60m to 2.70m) and north western corners (2.50m). The RTD typically comprised horizons of variably sandy/gravelly very soft to stiff CLAY, soft to firm SILT, and very loose to dense SAND/SAND & GRAVEL/GRAVEL. Softened or low density horizons were encountered in the majority of the exploratory holes with apparent random variably throughout the soil profile from depths of 0.30m to >4.00m.

Naturally Reworked London Clay was encountered underlying the Raised Beach Deposits locally in 2 No. exploratory holes in the north western corner of the site to depths of 1.50m and 1.80m respectively. It comprised horizons of soft sandy clayey SILT with numerous boulder-sized lenses of very soft silt and gravelly sand, and firm to stiff slightly gravelly CLAY with occasional boulder-sized lenses of sand and gravel.

The London Clay Formation was encountered underlying the River Terrace Deposits and locally the Naturally Reworked London Clay across the site from depths of 1.60m to 4.30m. It typically comprised horizons of firm to stiff CLAY. The top of the London Clay was locally softened in the southernmost section of the site in 3 No. exploratory holes from depths of 1.80-3.20m.

Groundwater was encountered at depths of 1.20m to 3.00m during the intrusive investigation as as slow to moderate (and occasionally fast) inflows and from depths of 0.00m to 3.10m during the subsequent initial monitoring visit.

Proposed Development

The site is proposed for residential development.

Geotechnical Conclusions & Recommendations

<u>Anticipated Foundation Types</u>

The principal geotechnical constraint with respect to foundations is the presence of identified random softened/low density horizons across the site and also potential random softened/low density horizons remaining undetected beneath shallow foundations, resulting in unacceptable differential settlements structures.

As such, the use of piled foundations are considered likely to be the preferred foundation option for the site. Driven piles, approximately 4-5m in length, are anticipated to be the most cost effective solution, however, other systems may be suitable such as vibro concrete columns. Consequently, it is recommended that a specialist piling contractor is contacted to provide the design and warranty of a suitable foundation solution for the site.

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Subject to additional investigation on a plot specific basis, traditional strip / trench fill foundations may locally be suitable; however, deepening of foundations is likely to be problematic due to anticipated excavation instability and the presence of shallow groundwater potentially reducing bearing capacities.

Raft foundations are not recommended at this stage (without further investigation and assessment) due to anticipated unacceptable differential settlements.

Vibro-stone columns are not considered suitable based on the presence of soft strata.

Ground improvement techniques such as lime stabilisation could potentially be undertaken to allow shallow/raft foundations to be used. However, the use of relatively short driven piles is considered likely to be more cost effective.

If piled foundations are adopted further investigation utilising deeper cable percussive boreholes will be required for pile design.

Other Considerations

Suspended floor slabs are recommended for the site based on the variable ground conditions.

ACEC Class AC-2 (Design Class DS-2) conditions are indicated to prevail on site.

A CBR design value of between <2% and 4.0% is recommended for the cohesive soils and geotechnically suitable Made Ground depending on localised conditions. Further Atterberg Limit testing of the cohesive soils at formation level is recommended to confirm this. A CBR design value of 20% is recommended for localised granular soils.

It was not possible to calculate soil infiltration rates in the natural strata due to the absence of significant infiltration, which was consistent with the predominantly cohesive strata and shallow groundwater encountered.

Environmental Risk Assessment & Liabilities

Risks to Site Users

Identified Sources: No significant contamination has been identified in the natural ground for the proposed residential end use.

Potential Risks: End users of the site and construction/maintenance workers are therefore not considered to be at significant risk from the site as no significant contaminant sources have been identified by the chemical analyses undertaken to date.

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Risks to Controlled Waters

Potential Sources: No significant soil sources have been identified.

Potential Risks: Risks to Controlled Waters are unlikely to be significant based on the information available.

Ground Gases

According to the preliminary gas monitoring results, the site is potentially characterised as NHBC 'Green'. However, further monitoring is recommended in particular in the north west near the off site landfill located 40m north west.

The site is not in a Radon Affected Area; as such no protective radon measures are required.

Remediation

Human Health Remedial Measures

Based on the information available, no remedial measures are considered necessary to protect human health.

Protection of Controlled Waters

No remedial measures are considered necessary to protect Controlled Waters from the site itself, based on the information available.

Further Investigation Requirements

The following further work is recommended:

- Deeper cable percussive boreholes for pile design purposes.
- Additional testing of the London Clay Formation due to the potential presence of pyritic sulphate.
- Further gas monitoring is recommended in particular in the north west near the off site landfill.

This executive summary is intended to provide an outline of the site assessment in relation to ground contamination and geotechnical parameters. It does not provide a definitive analysis of the information obtained.

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1. INTRODUCTION

1.1 General

Geo Environmental Group (GEG) were commissioned by Brookbanks Consulting Ltd (Brookbanks) on behalf of Hallam Land Management (HLM) (the Client) to undertake a Phase I Review & Phase II Geo-Environmental Assessment of a site known as 'Land at Pagham, West Sussex,' in order to provide relevant information with respect to the proposed residential development.

The purpose of this report was to determine:

- Potential environmental risks and liabilities associated with any potential soil and shallow groundwater contamination in accordance with current UK guidance (CLR 11) for a future residential end use.
- Geotechnical requirements for foundations, buried concrete, excavations, earthworks and slope stability with respect to the proposed residential development of the site.

1.2 Available Information

The following drawings were supplied by Brookbanks:

- Promap extract, unreferenced.
- 'Site Investigation Location Plan,' Brookbanks on behalf of HLM, Drawing No. 10461-SI-01, dated 15th January 2019.
- 'Land at Pagham, Bognor Regis, Geo-Environmental Desk Study,' WSP/Parsons Brinckerhoff on behalf of HLM, Ref. 70014147-R01, Rev. 01, dated 29th November 2019.
- Various utility company service drawings.

GEG also purchased additional utility company service drawings of the site.

1.3 Proposed Site Development

It is understood that the site is proposed for residential development; no further information is available at this stage.

1.4 Scope

The works performed by GEG included:

- A Phase I desk study review and preparation of a preliminary risk assessment and outline conceptual model.
- A Phase II intrusive investigation undertaken in accordance with a specification supplied by Brookbanks, comprising window sample boreholes, machine-excavated trial pits, infiltration testing and in-situ CBR testing.

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- Chemical analysis and geotechnical testing of selected soil samples.
- Gas and groundwater monitoring.
- Development of the conceptual model and generic quantitative human health and qualitative Controlled Waters environmental risk assessments in accordance with CLR11.
- A qualitative ground gas risk assessment in accordance with NHBC, CIRIA guidance, and British Standards.
- A geotechnical assessment (including foundations, floor slabs, buried concrete, road pavement design etc.) and including recommendations for suitability of the site for soakaway drainage.
- Recommendations for further investigation and/or remedial work (if required).
- Provision of a report documenting the above.

Limitations to the scope of the report are outlined in Section 11.

2. SITE SETTING

2.1 Site Location

The site is located in Pagham (approximately 4.5km west of the centre of Bognor Regis) in West Sussex, at the approximate National Grid Reference 489560E, 99180N. It lies on the western side of Hook Lane and east of Pagham Road and covers an area of approximately 17.5 hectares.

A section of the 1:25,000 Ordnance Survey (OS) map identifying the site location is shown in Figure 1 of Appendix A. The site layout plan is presented in Figure 2 (Appendix A) and a photographic record is provided in Appendix B.

2.2 Site Description

The site comprised 2 No. agricultural fields (south western and north eastern) with a westward-flowing drain trending in an east-west orientation along the internal hedged boundary between the fields. A second smaller section of drain was present on the north eastern site boundary.

Topographically, the site was relatively level at an elevation of approximately 5m AOD.

The boundaries of the site were typically hedged with occasional semi-mature deciduous trees particularly along the western boundary. A small electricity substation was located adjacent to the south eastern site boundary.

2.3 Adjacent Land Uses

A summary of surrounding land-use in the immediate vicinity of the site is provided below.

North Sefter Road followed by agricultural fields.

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East	Hook Lane followed by residential development (and including a small electricity substation located adjacent to the south eastern site boundary).
South	Hook Lane followed by residential development.
West	Pagham Road followed by agricultural fields and occasional residential dwellings in the southernmost and northernmost parts, and Rookery Farm within the southern part. Sefter Farm including 2 No. reservoirs and a pond is located 190m west of the site.

3. REVIEW OF AVAILABLE DESK STUDY INFORMATION

Available information relating to the history of the site, geology, hydrogeology and hydrology is summarised in the following sections extracted from the Phase I Desk Study Report undertaken by WSP/Parsons Brinckerhoff.

3.1 Landfills

According to the desk study, there is a record of 1 No. historical landfill site within 250m of the site, known as Sefter Lodge, located 40m north west and relating to the deposition of 27,000m^3 of inert, commercial and household waste from 1950 to 1960.

3.2 Waste Management

According to the desk study, there are no records of historical or operational waste treatment transfer or disposal sites within 250m of the site.

3.3 Discharge Consents

According to the desk study, there are 4 No. records of Discharge Consents within 250m of the site relating to sewage discharges 20m to 110m north and southwest and discharge of other matter/surface water 170-250m from the site in all directions.

3.4 Pollution Controls

No reference to pollution controls or authorisations were included within the desk study.

3.5 Pollution Incidents

No reference to Pollution Incidents to Controlled Waters were included within the desk study.

3.6 Hazardous Substances

No reference to hazardous substances were included within the desk study.

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3.7 Contemporary Trade Directories

According to desk study, records of 6 No. potentially contaminative industrial sites have been identified within 250m of the site relating to a variety of end uses typically comprising light industrial or commercial activities not considered to represent a significant impact on the site.

3.8 Ordnance

According to regional unexploded bomb risks maps (online viewer) provided by Zetica, the site falls within an area of low bomb risk and therefore no further action is required. However, the earlier desk study refers to the site as being in an area where the risk is moderate. According to the current online viewer, this refers to land associated with Bognor Regis approximately 175m east of the site, and does not include the site area itself.

3.9 Historical Information

3.9.1 Site History

According to the historical maps provided within the Desk Study, by 1880 the site comprised 2 No. agricultural fields in its current configuration. By 1976, a 'Drain' was identified along the internal field boundary. A second smaller section of 'Drain' was denoted along the north eastern site boundary in 2006. No further significant changes were identified.

3.9.2 Site Surroundings

According to the historical maps provided within the Desk Study, by 1880 the site surroundings typically comprised agricultural land. 4 No. 'Wells' were identified adjacent to the site: 2 No. 10m and 50m north west at 'Sefter Bottom'; 1 No. 25m south; and 1 No. 30m east. 'Rookery Farm' was also denoted 20m west (which included a pond and a fourth 'Well' 70m west).

By 1933, only the eastern and western 'Wells' remained, and 'Brick Fields' (indicating extraction of clay for brick manufacture) were denoted 115m east and 125m south of the site.

By 1961, the 'Brick Fields' were no longer marked, and pockets of residential development had taken place east of the site. By 1976, significant residential development had taken place east of the site, and no 'Wells' were marked near the site. Earthworks indicated 40m north west of the site likely related to the landfill identified in this area (see Section 3.1). No further significant changes were identified.

3.10 Geology

3.10.1 Published Geology

Reference to the 1:50,000 scale British Geological Survey digital mapping of the area (solid and drift) indicates that the solid geology beneath the site comprises the London Clay Formation of the Palaeogene period. It is described as poorly laminated, blue grey or grey brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. It commonly contains thin

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courses of carbonate concretions ('cementstone nodules') and disseminated pyrite. It also includes a few thin beds of shells and fine sand partings or pockets of sand.

The solid geology is conjectured to be overlain by superficial deposits of River Terrace Deposits (RTD) across the majority of the site, described generically as sand and gravel, locally with lenses of silt, clay or peat. The north westernmost corner of the site is conjectured to be overlain by Raised Beach Deposits 1, generically described as shingle, sand, silt and clay.

No faults are conjectured to intersect the site at the surface.

3.10.2 Mining and Quarrying

Reference to the Coal Authority interactive map viewer confirms that the site is not in a Coal Mining Reporting Area.

3.10.3 Potential Geo-Hazards

No significant potential geo-hazards such as underground workings, natural cavities, dissolution, landslips, compressible deposits, running sands or swelling clays were identified in the desk study report.

3.11 Hydrogeology

3.11.1 Groundwater Designation

The database search report indicates that the solid geology directly beneath the site is designated as Unproductive Strata.

Unproductive Strata - are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

The superficial deposits of the River Terrace Deposits are characterised as a Secondary A Aquifer and the Raised Beach Deposits as a Secondary Undifferentiated Aquifer.

Secondary A Aquifers are defined as permeable layers capable of supporting water supplies at a local rather than a strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

Secondary (undifferentiated) Aquifers are assigned where it is not possible to attribute either category A or B to a rock type. In general these layers have previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

3.11.2 Groundwater Source Protection Zone

The site does not lie within a currently defined Groundwater Source Protection Zone (GWSPZ).

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3.11.3 *Groundwater Abstractions*

According to the desk study report, there are no groundwater abstraction licences within 1000m of the site.

3.12 Hydrology

3.12.1 *Nearest Watercourse*

The nearest surface water feature is a drain on site flowing westwards towards the Pagham Rife 478m west of the site. A second smaller section of drain was present on the north eastern site boundary. A small pond was present 70m west of the site, as well as 2 No. reservoirs and a pond 190m north west.

3.12.2 *Surface Water Abstractions*

According to the desk study report, there are no surface water abstraction licences within 500m of the site.

3.12.3 *Surface Water Flooding*

According to the Environment Agency online 'Flood Map for Planning', the site lies within Flood Zone 1, being land that lies outside the 1 in 1000 year (0.1%AEP) flood risk area and hence has a low probability of flooding.

The land adjacent to the north west of the site in the vicinity of Rookery Cottage, however, is located within Flood Zone 3, with the smallest portion of Flood Zone 2 potentially overlapping the north westernmost tip of the northern site section.

Flood Zone 2: This zone comprises land assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year.

3.12.4 *Potential for Groundwater Flooding*

According to the desk study, no information regarding the groundwater depth or flow direction was available from the sources reviewed. However, shallow groundwater flow was anticipated to be generally westward towards the Pagham Rife.

3.13 Radon

The site is not in a Radon Affected Area, as only 1% to 3% of homes are estimated to be above the action level.

4. ENVIRONMENTAL RISK ASSESSMENT METHODOLOGY

4.1 Regulatory Controls

Contaminated land in England is principally controlled by:

- Part 2A of the Environmental Protection Act (1990) and accompanying Statutory Guidance.

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- Planning and Development Controls.

Part 2A relates to contaminated land risks from land in its current condition, whilst the planning and development control essentially is applicable to new developments which fall within the planning regime and applies to the proposed end use of the land.

These two key pieces of legislation are discussed further in the following sections together with other potentially relevant systems.

4.2 Environmental Protection Act - Part 2A

Part 2A of the Environmental Protection Act (1990) [EPA], which was introduced by section 57 of the Environment Act 1995, requires an overall risk-based approach to dealing with contaminated sites, to ensure that they are 'suitable for use'.

DETR Circular 02/2000 'Contaminated Land' which came into force in England on 1st April 2000 provided accompanying regulations and Statutory Guidance. This was superseded by DEFRA Circular 01/2006 'Contaminated Land' which included amendments to address land contaminated by radioactivity.

Definition of Contaminated Land

Contaminated land is defined in section 78A(2) of Part 2A as:

'Any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in on or under the land, that –

- Significant harm is being caused or there is a significant possibility of such harm being caused; or
- Pollution of controlled waters is being, or is likely to be caused.'

The Water Act 2003 s86 modified the definition of contaminated land to:

Any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in on or under the land, that –

- Significant harm is being caused or there is a significant possibility of such harm being caused; or
- Significant pollution of controlled waters is being caused, or there is a significant possibility of such pollution being caused.'

Recent changes to Part 2A require the local authority to use a four category system in order to decide whether or not land is designated as contaminated land.

Category 1 describes land which is clearly problematic e.g. because similar sites are known to have caused a significant problem in the past.

Categories 2 and 3 cover the less straightforward land where detailed consideration is needed before deciding whether it is contaminated land. The test rests on whether

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or not the Local Authority believes there is a strong case for regulatory action – and thus whether it should be placed into Category 2 (contaminated land) or Category 3 (not contaminated land). The decision basis is initially related to human health risks, and if this is not conclusive due to uncertainty over risks, wider socio-economic factors (e.g. cost, views of local people etc.).

Category 4 describes land that is clearly not contaminated land. The new Category 4 test is particularly important in terms of reducing uncertainty over when land is clearly not contaminated land in the legal sense. Land at or below SGV/GAC levels derived using the CLEA methodology is likely to be well within Category 4. DEFRA are currently in the process of producing Category 4 screening levels. PT2A states that normal levels of contaminants in soil should not be considered to cause land to qualify as contaminated land, unless there is a particular reason to consider otherwise. DEFRA have commissioned BGS to produce a report determining normal levels of contaminants in UK soils.

Once land has been determined as contaminated land, the enforcing authority must consider how it should be remediated and, where appropriate, it must issue a remediation notice to require such remediation. The enforcing authority for the purposes of remediation may be the local authority which determined the land, or the Environment Agency, which takes on responsibility once land has been determined if the land is deemed to be a "special site". The rules on what land is to be regarded as special sites, and various rules on the issuing of remediation notices, are set out in the Contaminated Land (England) Regulations 2006.

'Special Sites'

In certain cases, the Environment Agency is the regulatory authority for the contaminated land legislation. This arises if the site under investigation has been used for certain processes, or if the site is situated on bedrock classed as a Principal Aquifer (i.e. water-bearing strata). In the legislation, these sites are referred to as "Special Sites".

4.3 Planning and Development Controls

The Part 2A contaminated land regime will not normally apply where land is being managed within the normal cycle of land redevelopment and regeneration, where planning and development control will continue to be the primary means of control.

Land contamination, or the possibility of it, is a material consideration for the purposes of town and country planning. Current planning control on contaminated land is set out in **National Planning Policy Framework (2018),** which was published in July 2018, and replaces the original 2012 NPPF.

National Planning Policy Framework (England) is intended to complement the pollution control framework under the Pollution Prevention and Control Act 1999 and the PPC Regulations 2000.

In addition to the planning system, the **Building Regulations 1991** (made under the Building Act 1984) may require measures to be taken to protect the fabric of new buildings, and their future occupants, from the effects of contamination. Approved Document Part C (Site Preparation and Resistance to Contaminates and Moisture) 2004 edition gives guidance on these requirements.

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4.4 Environmental Protection Act 1990 Part III – Statutory Nuisance

Statutory nuisance provisions will no longer apply where the nuisance arises in relation to land in a 'contaminated state'. However, nuisance provisions could still apply where land gives rise to a nuisance (such as an odour) that is an offence to human senses but which is not covered under the various categories of harm set out in the Contaminated Land Statutory Guidance.

4.5 Permitted Installations

Part 2A will not apply where the Environment Agency or the Local Authority has powers under Integrated Pollution Prevention and Control (IPPC) provisions of the Environmental Permitting Regulations 2007 to take action to remedy contamination resulting from the breach of an installation permit.

Waste Management Licensing (Part II of EPA 1990)

Part 2A will not normally apply where contamination has resulted from land subject to a waste management licence, although it may apply where adverse effects arise from causes other than a breach of licence conditions or from activities that are permitted under the licence. Licences are regulated and issued by the Environment Agency.

Waste management licensing is currently being incorporated into the Environmental Permitting Regulations (see Permitted Installations).

4.6 Water Resources Act (WRA) 1991

Sections 161 to 161D of the Water Resources Act 1991 give the Environment Agency powers to take action to prevent or remedy the pollution of controlled waters. The Agency can serve a 'works notice' on any person who has 'caused or knowingly permitted' potential pollution to be in a place from which it is likely to enter controlled waters, or to have caused or knowingly permitted a pollutant to enter controlled waters. The works notice specifies what actions have to be taken in what time periods. Where urgent action is required or a works notice is not complied with, the Agency has the power to carry out the works itself and recover costs from the appropriate person.

The Water Resources Act may apply where the Part 2A regime does not, for example where there is historical pollution of groundwater.

The Water Act 2003 includes a provision, not yet commenced, to amend the current Part 2A definition of pollution of controlled waters to introduce a 'significance' test. The Government propose to return to this issue when a significance test for radioactive and non-radioactive contamination can be considered together.

4.7 Groundwater Regulations (GWR) 2009

The existing Groundwater Directive (80/68/EEC) aims to protect groundwater from pollution by controlling discharges and disposals of certain dangerous substances to groundwater. In the UK, the directive is implemented through the Groundwater Regulations (GWR) 2009.

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Groundwater is protected under these regulations by preventing or limiting the inputs of polluting substances into groundwater. Substances controlled under these regulations fall into two categories:

- **Hazardous** substances are the most toxic and must be prevented from entering groundwater. Substances in this list may be disposed of to the ground, under a permit, but must not reach groundwater. They include pesticides, sheep dip, solvents, hydrocarbons, mercury, cadmium and cyanide. Hazardous substances replace the previous List 1 substances which came under the 1998 GWR.
- **Non-hazardous pollutants** are less dangerous, and can be discharged to groundwater under a permit, but must not cause pollution. Examples include sewage, trade effluent and most wastes. Non-hazardous pollutants include any substance capable of causing pollution and the list is much wider than the previous List 2 substances. For example, nitrate is included as a pollutant but it was excluded from List 2 in the 1998 GWR.

The existing Groundwater Directive is to be repealed by the Water Framework Directive 2000/60/EC (WFD) in 2013. The GWR 2009 has recently been made law to enact both the WFD and its Daughter Directive 2006/118/EC on the protection of groundwater. This new Groundwater Directive (2006/118/EC) is commonly referred to as the Groundwater Daughter Directive (GWDD).

4.8 Suitable for Use Approach

In practice, most sites with a previous potentially contaminating history are remediated to a condition 'suitable for use' under the planning regime rather than the Part 2A legislation.

The 'suitable for use' approach outlined in DEFRA Circular 01/2006 consists of the following three elements:

- Ensuring that land is suitable for its current use.
- Ensuring that land is made suitable for any new use, as planning permission is given for that new use.
- Limiting requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to the current use or future use of land for which planning permission is being sought.

Where new development is taking place, it will be the responsibility of the developer to carry out the necessary remediation. In most cases, the enforcement of any remediation requirements will be through planning conditions and building control, rather than through a remediation notice issued under Part 2A.

4.9 Assessment Methodology

The DEFRA and Environment Agency Contaminated Land Report 11 (CLR11) 'Model Procedures for the Management of Land Contamination' provides a technical framework for structured decision making about land contamination.

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Definition of Risk

CLR11 defines risk as:

- A combination of probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

The Concept of the 'Pollutant Linkage'

In the context of contaminated land, there are three essential elements to any risk:

- A **contaminant (or source)** – a substance that is in, on or under land and has the potential to cause harm or cause pollution of Controlled Waters.
- A **receptor** - humans, ecological system, water body or property.
- A **pathway** – a route or means by which a receptor can be exposed to, or affected by, a contaminant.

Each of these elements can exist separately; however, they create a risk only where they are linked together forming a **pollutant linkage**.

Conceptual Site Models

A conceptual site model represents the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.

The Tiered Risk Assessment Approach

CLR11 presents a tiered approach to risk:

Tier 1 *Preliminary risk assessment (PRA)*

The purpose of the preliminary risk assessment is to develop an initial conceptual model of the site and to establish whether or not there are potentially unacceptable risks. If potential risks are identified the initial conceptual model is developed in subsequent tiers of the risk assessment process.

Tier 2 *Generic quantitative risk assessment (GQRA)*

The purpose of the generic quantitative risk assessment is to establish whether generic assessment criteria and assumptions are appropriate for assessing the risks and, if so, to apply them to establish whether there are actual or potential unacceptable risks. It also determines whether further detailed quantitative risk assessment is required.

Tier 3 *Detailed quantitative risk assessment (DQRA)*

The purpose of the detailed quantitative risk assessment is to establish and use more detailed site specific information and criteria to decide whether there are

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unacceptable risks. It may be used as the sole method of quantitative assessments of risks, or it may be used to refine earlier assessments using generic assessment criteria.

5. PRELIMINARY RISK ASSESSMENT AND OUTLINE CONCEPTUAL MODEL

5.1 Potential Contaminants of Concern

Based on the historical and current usage of the site as agricultural land, potential **on-site** contamination sources are likely to be limited to:

- Any localised spillages or leakages of fuel or oils from farm machinery/vehicles.
- Pesticides and herbicides sprayed on the site (including the more persistent historical organochlorine pesticides including aldrin, DDT, dieldrin and endrin now banned in the UK).
- Any historically imported contaminated Made Ground used to raise site levels/infill voids or fly-tipped material.

The potential **off-site** contamination sources are likely to be associated with the following current and historical uses:

- Any historically imported contaminated Made Ground used to raise site levels/infill voids (such as the infilled historical 'brick fields' identified 115m east and 125m south of the site).
- The electricity sub-station located adjacent to the eastern section of the site.
- Landfill gas and leachates associated with the landfill 40m north west of the site.

The potential contaminants of concern associated with the current and historical land uses outlined above include:

- Herbicides / pesticides (including aldrin, DDT, dieldrin and endrin).
- Petroleum hydrocarbons (TPH) and polyaromatic hydrocarbons (PAHs).
- General contaminants including metals, semi-metals and non-metals, inorganic chemicals and organics.
- Polychlorinated biphenols (PCBs).
- Ground gases (including methane and carbon dioxide).

A diagrammatic illustration of the outline conceptual model is presented in Figure 3 of Appendix A.

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5.2 Preliminary Human Health Conceptual Model

Potential Sources: Potential and identified contamination associated with the usage of the site and adjacent land as detailed in Section 5.1.

Potential Pathways: Ingestion of soil and dust, dermal contact with soil and dust, ingestion of home grown produce and attached soil, inhalation of soil and dust, and the inhalation of indoor and outdoor vapours and ground gases. Potential combustion or explosion of ground gases in confined spaces.

Potential Receptors: Future site users (residents, site workers, visitors, construction/maintenance workers and potential trespassers) and adjacent residents. Also site flora and fauna and future buildings/structures and construction materials (e.g. water supply pipes).

5.3 Preliminary Controlled Waters Conceptual Model

Potential Sources: Potential and identified contamination associated with the usage of the site and adjacent land as detailed in Section 5.1.

Potential Pathways: Infiltration of precipitation through the site's surface and leaching of potential contaminants and subsequent vertical migration to the aquifer or horizontal migration to the watercourse.

Potential Receptors: Underlying groundwater in the Secondary A and Undifferentiated Aquifers; on site drains, pond 70m west, and 2 No. reservoirs and a pond 190m north west. (The groundwater and surface water abstractions are considered too distant from the site to be at significant risk).

5.4 Preliminary Ground Gas Assessment

There are records of a historical landfill site 40m north west (which accepted inert, commercial and household waste from 1950 to 1960), as well as a potential for infilled ground relating to shallow opencast 'brick fields' 115m east and 125m south of the site. However, there is no evidence to suggest that there is a significant thickness of Made Ground on the site itself. Consequently, based on guidance given in Figure 6 of BS 8576:2013, the gas generation potential of the sources identified are considered to be low to moderate at this stage. (Further assessment is presented in the environmental conclusions in Section 9.2.)

As previously described, the site is not in a Radon Affected Area.

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6. INTRUSIVE INVESTIGATION

The following section outlines the scope of the intrusive investigation carried out by GEG in accordance with the Brookbanks specification and details the ground conditions encountered and the chemical testing undertaken.

6.1 Site Works

6.1.1 General

The intrusive investigation was undertaken from 22nd to 25th October 2019 in accordance with the Brookbanks Specification, current British Standard guidance (BS:5930 and BS:10175) and ICE UK Specification for Ground Investigation (2nd Edition 2012) guidelines and comprised window sample boreholes, machine-excavated trial pitting, infiltration testing and in-situ CBR testing.

Prior to commencement of the works, service plans were viewed in order to investigate the location of all major services and each exploratory hole location screened with a cable avoidance tool.

The exploratory holes were logged and sampled by an experienced geo-environmental engineer from GEG. The ground conditions encountered were recorded on the exploratory hole logs (Appendix C). Where strengths and relative densities are in brackets on the exploratory hole logs, these are based on visual assessment in accordance with BS:5930, in the absence of in-situ or laboratory tests.

The locations of the exploratory holes as determined by Brookbanks are shown on Figure 4 presented in Appendix A.

6.1.1.1 Limitations of the Intrusive Investigation

There were no significant limitations to access across the site for the duration of the intrusive investigation. However, due to soft ground conditions at surface (following a period of prolonged heavy rainfall), the window sample boreholes were repositioned towards the field boundaries in the southern and central parts of the site. Furthermore, as the nature of the underlying ground conditions typically exhibited a degree of instability during excavation of the trial pits, TP33 was omitted due to the increased time required to complete the remaining trial pits.

6.1.2 Window Sample Holes

9 No. window sample boreholes (WS01-WS09) were drilled using a Competitor Dart dynamic sampling rig to a maximum depth of 5.50m.

Continuous sampling was undertaken using a liner system and standard penetration tests (SPTs) were carried out in each hole to confirm the strength/relative density.

WS01, WS05 and WS09 were installed with 50mm diameter standpipes to depths detailed on the exploratory hole logs for subsequent gas and groundwater monitoring.

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6.1.3 *Trial Pits*

41 No. trial pits (TP01-TP06, TP08-TP32, TP34-TP39, IT41-IT43 & TP44) were excavated using a JCB-3CX to a maximum depth of 4.00m to facilitate investigation of the near surface soils.

TP33 was not undertaken as outlined in Section 6.1.1.1.

A further 2 No. trial pit designations (TP07 & TP40) were specified for in-situ CBR testing only (and re-labelled CBR7 & CBR40, as shown on Figure 4, Appendix A) and as such no corresponding trial pit logs are provided.

The trial pit numbering system was in general accordance with drawings provided by Brookbanks Consulting.

6.1.4 *Hand Excavated Pits*

1 No. hand pit (PCB01) was excavated to a depth of 0.20m to facilitate investigation of the near surface soils adjacent to the existing electricity substation.

6.1.5 *Reinstatement*

The trial pits were backfilled with arisings and left mounded to allow for settlement. Boreholes were also backfilled with arisings or in the case of boreholes WS01, WS05 and WS09 installed with 50mm diameter gas and groundwater monitoring standpipes and a lockable flush cover.

6.1.6 *Rationale for Exploratory Holes*

The rationale for the exploratory locations, which was undertaken in general accordance with the Brookbanks' specification, is given in Table 1 below. A plan showing the location of the exploratory holes is included as Figure 4.

Table 1. Rationale for Exploratory Holes

Exploratory Hole	Rationale
WS01-WS09, TP01-TP06, TP08-TP32, TP34-TP39 & TP44	General site coverage (9 No. window sample boreholes & 38 No. trial pits).
IT41-IT43	Infiltration testing in the northern part of the site (3 No. infiltration test pits).

6.1.7 *In-situ CBR Testing*

In-situ CBR testing was undertaken in 6 No. shallow trial pits in accordance with BS 1377-1:1990. The results are presented in Table 2 below.

Table 2. In-situ CBR test results

Exploratory Hole / Depth	Soil Type	Strata*	In Situ CBR Value
CBR7 / 0.40m	CLAY	RTD	7.80%

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Exploratory Hole / Depth	Soil Type	Strata*	In Situ CBR Value
CBR9 / 0.40m	CLAY	RTD	3.50%
CBR15 / 0.40m	CLAY	RTD	1.10%
CBR21 / 0.40m	CLAY	RTD	2.60%
CBR24 / 0.40m	CLAY	RTD	1.00%
CBR31 / 0.40m	CLAY	RTD	1.40%

*RTD=River Terrace Deposits

6.1.8 *Sampling*

Samples were taken from the exploratory holes for geotechnical and chemical testing as described in Section 6.2 and 6.3 respectively.

6.1.9 *Infiltration Tests*

3 No. infiltration tests in 3 No. trial pits (IT41-IT43) were undertaken in general accordance with BRE Digest 365.

Trial pits IT41-IT43 were excavated to depths of 1.80m to 2.00m and infiltration tests undertaken in the most permeable strata. Clean water was dispensed from a bowser at a rapid rate to fill each excavation as quickly as possible to the proposed depth of the invert levels and/or the most permeable strata. The excavations took less than 5 minutes to fill to the maximum capacity.

Measurements were then taken of the fall of water at suitable time increments to allow the infiltration rate to be calculated from the time taken for the water level to drop from 75% to 25% effective depth (where possible).

On completion of the measurements, the infiltration pits were backfilled with arisings.

The water level measurements from the infiltration tests are tabulated and graphically depicted on Figures D-1 to D-3 in Appendix D. The results are summarised in Table 3.

Table 3. Infiltration Test Results

Location (Depth Range of Test)	Test No.	Strata*	Effective Depth Reached	Time (mins)	Infiltration Rate (m/s)
IT41 (0.79-2.00m)	1	RTD	100%	282	N/A
IT42 (0.52-1.80m)	1	RTD/LCF	100%	255	N/A

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Location (Depth Range of Test)	Test No.	Strata*	Effective Depth Reached	Time (mins)	Infiltration Rate (m/s)
IT43 (0.55-2.00m)	1	RBD/LCF	105%	267	N/A

N/A = not applicable
* RTD=River Terrace Deposits; RBD=Raised Beach Deposits; LCF=London Clay Formation

As shown in Table 3, the water levels in IT41 and IT42 showed very little infiltration and rose (due to groundwater ingress) in IT43 and consequently no infiltration rates could be calculated.

6.1.10 Gas and Groundwater Monitoring

6.1.10.1 Rationale for Gas Monitoring

The ground conditions encountered in the exploratory holes confirmed natural ground across the majority of the site. However, there is a landfill 40m north west. This is considered consistent with the low to moderate gas generation potential identified in the Preliminary Ground Gas Assessment (Section 5.4). Consequently, in accordance with Figure 6 of BS8576:2013, gas monitoring is not necessarily a requirement; however, 3 No. initial visits were undertaken for confirmatory purposes, as detailed below.

6.1.11 Monitoring Programme

Monthly gas and groundwater monitoring is ongoing targeting periods of falling atmospheric pressure where possible. To date monitoring has been undertaken on 14th November 2019. The standpipes were monitored for methane, carbon dioxide, oxygen, hydrogen sulphide and the borehole flow rate using a GA2000 gas analyser. Atmospheric pressure and trend was also recorded.

Table 4. Gas Monitoring Results

Borehole	Date	Atmospheric Pressure (mb)	Atmospheric Pressure Trend	Methane (% Vol.)	Carbon Dioxide (% Vol.)	Oxygen (% Vol.)	Hydrogen Sulphide (ppm)	Borehole Flow (l/hr)
WS01	14/11/19	987	Falling	0.0	0.6	20.2	0	0.0
WS05	14/11/19	987	Falling	0.0	4.1	14.2	0	0.0
WS09	14/11/19	988	Falling	0.0	2.2	19.0	0	0.0

The gas monitoring recorded methane concentrations of 0.0% and carbon dioxide concentrations of 0.6% to 4.1% with a maximum borehole flow rate 0.0 l/hr.

The water levels were monitored using a dip meter; results are presented in Section 6.4.6.

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6.2 Geotechnical Laboratory Testing

Selected samples were despatched to Geo Site and Testing Services Limited and scheduled for geotechnical testing. The schedule of testing comprised:

- 10 No. natural moisture contents (BS1377: Part 2: 1990: 3.2).
- 10 No. liquid and plastic limits (BS1377: Part 2: 1990: 4.2-4.4 & 5.2-5.4).
- 5 No. particle size distribution wet sieve method (BS1377: Part 2: 1990: 9.2).
- 5 No. sedimentation by pipette carried out with wet sieve (BS1377: Part 2: 1990: 9.4).
- 5 No. dry density/moisture content relationship, 4.5kg rammer Method 1 litre mould (BS1377: Part 4: 1990: 3.5).
- 3 No. quick undrained triaxial compression test - single specimen at one confining pressure (100mm or 38mm diameter) (BS1377: 1990 Part 7: 8).
- 3 No. one-dimensional consolidation 75mm or 50mm diameter specimens (5 days) (BS1377: Part 5: 1990: 3).

10 No. water soluble sulphate, soluble magnesium, chloride and pH determinations were also undertaken on the natural soils as part of the chemical testing (Section 6.3).

6.3 Chemical Laboratory Testing

6.3.1 Schedule of Analysis

Representative samples of natural ground were despatched to DETS Ltd for chemical analysis.

The schedule of analysis as detailed below comprised a combination of a range of contaminants commonly identified on brownfield sites, together with specific determinands based on the former and current site and adjacent site uses, as identified below. All soil analysis was MCerts accredited where possible.

Soils

Metals:	Cadmium, chromium (total, III and VI), copper, lead, nickel, zinc, mercury, antimony.
Semi-Metals and Non-Metals:	Arsenic, boron, selenium.
Inorganic Chemicals:	Cyanide (total and free), sulphate (soluble), sulphide.
Others:	pH, soil organic matter
Organics:	Total phenols, banded petroleum hydrocarbons (TPHs), speciated polycyclic

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aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCBs)*, SVOC pesticide screen.

** Selected samples only*

6.3.2 *Scope of Analysis*

The scope of the chemical testing as outlined in Section 6.3.1 is summarised in Table 5 below.

Table 5. Scope of Natural Ground Chemical Testing

Sample Type	Analyses	No.	Rationale
Natural Ground	General Suite	9	General coverage
	SVOC Pesticide Screen	9	
Natural Ground	PCBs	1	Targeted adjacent to electricity substation on south eastern boundary of the site.

6.4 Ground Conditions Encountered

The ground conditions encountered are described below and broadly confirmed the published geology. The strength/relative density of the strata is detailed further in the geotechnical assessment in Section 8.1.

6.4.1 *Topsoil*

Typically soft to firm CLAY topsoil was encountered across the site to depths of 0.30m to 0.50m.

6.4.2 *Raised Beach Deposits*

Raised Beach Deposits were encountered underlying the topsoil locally in 2 No. exploratory holes (IT42 & IT43) in the north western corner of the site to depths of 0.70m and 0.90m respectively. This strata comprised variably sandy/gravelly soft to firm CLAY and loose to medium dense GRAVEL.

6.4.3 *River Terrace Deposits*

River Terrace Deposits (RTD) were encountered underlying the topsoil to depths ranging from 1.60m to 4.30m across the majority of the site, with the exception of the north westernmost corner. These deposits were typically found to be in excess of 3.00m in thickness across the central and north eastern sections of the site, becoming thinner towards the south western (1.60m to 2.70m) and north western corners (2.50m). The RTD typically comprised horizons of variably sandy/gravelly very soft to stiff CLAY, soft to firm SILT, and very loose to dense SAND/SAND & GRAVEL/GRAVEL. Softened or low density horizons were encountered in the majority of the exploratory holes (with the exception of WS08, TP09 TP16, TP38 & TP39) with apparent random variably throughout the soil profile from depths of 0.30m to >4.00m.

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6.4.4 *Naturally Reworked London Clay*

Naturally Reworked London Clay was encountered underlying the Raised Beach Deposits locally in 2 No. exploratory holes (IT42 & IT43) in the north western corner of the site to depths of 1.50m and 1.80m respectively. This strata comprised horizons of soft sandy clayey SILT with numerous boulder-sized lenses of very soft silt and gravelly sand, and firm to stiff slightly gravelly CLAY with occasional boulder-sized lenses of sand and gravel.

6.4.5 *London Clay Formation*

The London Clay Formation was encountered underlying the River Terrace Deposits and locally the Naturally Reworked London Clay across the site from depths of 1.60m to 4.30m. It comprised horizons of firm to stiff CLAY. The top of the London Clay was locally softened in the southernmost section of the site (e.g. WS07 1.80-2.70m; TP35 2.70-3.20m; TP36 2.30 to 2.50m).

6.4.6 *Groundwater*

Groundwater was encountered in the majority of the exploratory holes during the investigation across the site from depths of 1.20m to 3.00m as slow to moderate (and occasionally fast) inflows.

Groundwater levels recorded in the boreholes during the subsequent monitoring visits are summarised in Table 6.

Table 6. Groundwater Levels Recorded During the Monitoring Visits

Borehole	Date	Depth of Installation (m)	Groundwater Depth (m)
WS01	14/11/19	5.00	0.50
WS05	14/11/19	5.00	0.00
WS09	14/11/19	4.00	0.90

It should be noted that groundwater levels may vary due to seasonal and other effects.

6.4.7 *Stability of Trial Pits*

The majority of trial pit excavations encountered instability of the sides at depths of 2.00m to 4.00m (and occasionally from 1.00m).

6.4.8 *Visual and Olfactory Evidence of Contamination*

No visual or olfactory evidence of contamination was encountered in any of the exploratory holes undertaken.

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7. GENERIC HUMAN HEALTH QUANTITATIVE RISK ASSESSMENT

7.1 Generic Human Health QRA

7.1.1 CLEA

A generic human health quantitative risk assessment has been undertaken primarily using generic assessment criteria (GAC) derived in CLEA, assuming a 'sand' soil type of pH 7 and SOM of 1% were used in the assessment of the natural ground.

The 'residential with home grown produce' for a semi-detached property has been used in the assessment as this is the most sensitive generic land use and building type in the CLEA model applicable to the proposed development.

The exposure pathways used in the CLEA model were:

- Ingestion of soil and dust
- Ingestion of home grown produce and attached soil
- Dermal contact with soil and dust
- Inhalation of soil and dust
- Inhalation of vapours outdoors
- Inhalation of vapours indoors

7.1.2 Other Assessment Criteria

EIC/AGS/CL:AIRE GAC have been used where available for organic compounds not covered by the CLEA Model. In the absence of these, the Risk Based Corrective Action (RBCA) Toolkit has been used.

A GEG in-house GAC for total cyanide (for all end uses) has been derived based on acute toxicity and a one-time soil ingestion event.

Sulphate and sulphide were not assessed as these contaminants are not generally considered to represent a significant risk to human health unless at extremely high levels.

Reference has also be made to the DEFRA Category 4 Screening Levels. These were initially derived for categorizing land affected by contamination in accordance of Part 2A of the Environmental Protection Act 1990 (as amended), but subsequently confirmed by Parliamentary Under Secretary of State for Natural Environment and Science Lord Mauley for use in the planning process. This was endorsed with respect to PAHs by Public Health England (2017).

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7.1.3 *PAH Profiling*

Methodology

Public Health England (2017) has recommended benzo(a)pyrene as a surrogate marker for the assessment of the risks posed by genotoxic PAH compounds where sufficiently similar to the 2 No. coal tar mixtures investigated by Culp *et al.* (1998).

By using a PAH profiling tool, it is possible to assess how closely the ratio of benzo(a)pyrene correlates to the standard mixtures of PAHs. If the mean results are within ±x10 of the 2 No. coal tar mixtures then it is possible to use benzo(a)pyrene as a surrogate PAH marker.

Assessment

PAH profiling has not been undertaken for the site as all benzo(a)pyrene concentrations were below the laboratory detection limit.

7.1.4 *Vapour Risk Associated with PAHs*

PAHs (including benzo(a)pyrene) are typically of low volatility. However, selected compounds including naphthalene and to a lesser degree dibenzo(ah)anthracene, benzo(a)anthracene, and ideno(123-cd)pyrene are of higher volatility. Consequently, GEG consider that the benzo(a)pyrene surrogate marker approach could potentially not fully characterise vapour risks for PAHs, particularly if mixtures are present containing for example naphthalene. As such GEG screen individual PAHs against inhalation health criteria values (IHCV) derived in CLEA in order to assess these risks.

7.2 Statistical Analysis of Soil Chemical Data

7.2.1 *Methodology*

The chemical analysis results from this investigation have been subjected to statistical analysis as detailed in the guidance produced by the Chartered Institute of Environmental Health (CIEH) (CIEH/CL:AIRE, May 2008) where sufficient data is available.

For details of the statistical tests and hypotheses, reference should be made to the aforementioned publication. However, a brief overview is presented below.

In the first instance, a Null Hypothesis (H_0) and Alternative Hypothesis (H_1) are defined as below, in this case based on the Planning Scenario:

H_0 $\mu \geq Cc$ i.e. the true mean concentration (μ) is equal to or greater than the critical concentration (Cc)

H_1 $\mu < Cc$ i.e. the true mean concentration (μ) is less than the critical concentration (Cc)

The data is firstly split into averaging areas based on historical site uses etc. For this site the data has been designated as natural ground soil concentrations where

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random sampling was undertaken (as the statistical analysis is not applicable for targeted sampling).

An outlier test (Grubb's Test) is undertaken to determine whether the soil concentrations for each determinand and averaging area belong to the same or are part of a separate population i.e. represent outliers or 'hot spots'.

A normality test is then undertaken to determine if the data is normally distributed, or otherwise.

A significance test (dependent upon the distribution of the data) is then applied to the data to test H_0 and H_1, and determine the associated level of evidence against H_0.

The GAC are used as critical concentrations in the assessment.

The one sample t-test is undertaken for Normal data and the Chebychev test for Non-normal data. The former derives a single value for the level of evidence against H_0, whereas the latter derives upper and lower bound values.

The ESI Ltd Contaminated Land Statistical Calculator has been used to undertake the aforementioned statistical assessments and the output tables are presented in Appendix F and summarised in the following sections.

7.2.2 Natural Ground - Non-Targeted Sampling

Statistical analysis of the chemical data from the 9 No. samples of natural ground did not identify any outliers or 'hotspots' above the relevant critical concentrations and the upper confidence limits of the true mean were also below the relevant critical concentrations (indicating the absence of widespread contamination) for all determinands including:

- Metals (arsenic, cadmium, total chromium, chromium III, chromium VI, copper, lead, mercury, nickel and zinc antimony).
- Semi-metals and non-metals (boron and selenium).
- Inorganic chemicals (total and free cyanide).
- Organics (total phenols, C6-C40 banded petroleum hydrocarbons, USEPA 16 polycyclic aromatic hydrocarbons [naphthalene, acenaphthylene, acenaphthene, fluorine, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(123-cd)pyrene, dibenzo(ah)anthracene and benzo(ghi)perylene].

7.2.2.1 SVOC Pesticides

Pesticide testing is currently ongoing and will be included at a later date.

7.2.2.2 PCBs

No PCB congeners were identified above laboratory detection in the 1 No. sample of natural ground screened.

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7.3 Summary of Soil Contamination

No elevated soil contaminants have been identified.

7.4 Generic Controlled Waters Quantitative Risk Assessment

No significant sources of contamination have been identified by the soil analyses undertaken.

7.5 Ground Gas Risk Assessment

The preliminary gas monitoring results recorded have been assessed using guidance presented in CIRIA C665 and BS8485 for 'Assessing risks posed by hazardous ground gas to buildings' for 'low rise traditional housing' in order to reflect the most sensitive aspects of the proposed development. Using a maximum concentrations of methane and carbon dioxide of 0.0% and 4.1% respectively, and the maximum recorded borehole flow rate of 0.0 l/hr, this corresponds to gas screening values (GSV) of 0.00 l/hr and 0.00 l/hr respectively. Therefore, according to Table 8.7 of CIRIA C665 (for use for low-rise traditional housing) using the GSV the site is provisionally characterised as NHBC 'Green'. However, monitoring is ongoing and further monitoring is recommended in particular in the north west near the off site landfill.

As previously described, no protective radon measures are required.

8. GEOTECHNICAL CONCLUSIONS AND RECOMMENDATIONS

8.1 Overview

8.1.1 Summary of Strata Encountered

Typically soft to firm CLAY topsoil was encountered across the site to depths of 0.30m to 0.50m.

Raised Beach Deposits were encountered underlying the topsoil locally in 2 No. exploratory holes in the north western corner of the site to depths of 0.70m and 0.90m respectively. This strata comprised horizons of variably sandy/gravelly soft to firm CLAY and loose to medium dense GRAVEL.

River Terrace Deposits (RTD) were encountered underlying the topsoil to depths ranging from 1.60m to 4.30m across the majority of the site, with the exception of the north westernmost corner. These deposits were typically found to be in excess of 3.00m in thickness across the central and north eastern sections of the site, becoming thinner towards the south western (1.60m to 2.70m) and north western corners (2.50m). The RTD typically comprised horizons of variably sandy/gravelly very soft to stiff CLAY, soft to firm SILT, and very loose to dense SAND/SAND & GRAVEL/GRAVEL. Softened or low density horizons were encountered in the majority of the exploratory holes with apparent random variably throughout the soil profile from depths of 0.30m to >4.00m.

Naturally Reworked London Clay was encountered underlying the Raised Beach Deposits locally in 2 No. exploratory holes in the north western corner of the site to

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depths of 1.50m and 1.80m respectively. It comprised horizons of soft sandy clayey SILT with numerous boulder-sized lenses of very soft silt and gravelly sand, and firm to stiff slightly gravelly CLAY with occasional boulder-sized lenses of sand and gravel.

The London Clay Formation was encountered underlying the River Terrace Deposits and locally the Naturally Reworked London Clay across the site from depths of 1.60m to 4.30m. It typically comprised horizons of firm to stiff CLAY. The top of the London Clay was locally softened in the southernmost section of the site in 3 No. exploratory holes from depths of 1.80-3.20m.

8.1.2 Groundwater

Groundwater was encountered at depths of 1.20m to 3.00m during the intrusive investigation as as slow to moderate (and occasionally fast) inflows and from depths of 0.00m to 3.10m during the subsequent initial monitoring visit.

It should be noted that groundwater levels may vary due to seasonal and other effects.

8.1.3 Trial Pit Stability

The majority of trial pit excavations encountered instability of the sides at depths of 2.00m to 4.00m (and occasionally from 1.00m).

8.1.4 Undrained Shear Strength

8.1.4.1 Pocket Penetrometer - Unconfined Compressive Strength

2 No. in-situ pocket penetrometer tests recorded unconfined compressive strengths (UCS) of 0.00 kN/m² in the cohesive strata of the River Terrace Deposits at depths of 1.50m and 2.50m. Measurements of 0.00 kN/m² are at or below the instrumental lower limit of the penetrometer. This indicates very soft strata.

8.1.4.2 Uncorrected Hand Vane Measurements

In-situ hand shear vane tests recorded undrained shear strengths of 4 kN/m² to 169 kN/m² from 0.50m to 2.30m in the cohesive strata of the River Terrace Deposits, as shown on Graph 1 (Appendix G).

In-situ hand shear vane tests recorded undrained shear strengths of 18 kN/m² to 150 kN/m² from 1.50m to 3.90m in the cohesive strata of the London Clay Formation, as shown on Graph 1 (Appendix G).

8.1.4.3 Standard Penetration Tests (SPT) 'N' Values – Shear Strength

9 No. SPTs undertaken in the natural cohesive River Terrace Deposits, recorded 'N' values of 1 to 17 at depths of 1.00m to 4.00m, which based on the relationship: Cu = f1 x N after Stroud 1974, where f1 is assumed as 4.5, corresponds to undrained shear strength (Cu) of 5 to 77 kN/m² respectively. The data is shown in Graph 2 (Appendix G).

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8 No. SPTs undertaken in the natural cohesive London Clay Formation, recorded 'N' values of 6 to 28 at depths of 2.00m to 4.00m, which based on the relationship: Cu = f1 x N after Stroud 1974, where f1 is assumed as 5, corresponds to undrained shear strength (Cu) of 30 to 140 kN/m² respectively. The data is shown in Graph 2 (Appendix G).

8.1.4.4 Geotechnical Laboratory Testing

Recorded undrained shear strength results from the 3 No. quick undrained triaxial compression tests ranged from 50 kPa to 125 kPa at depths of 0.50m to 4.50m. However, it is noted that these tests were undertaken on samples taken from window sample boreholes which may have suffered a degree of consolidation during drilling. This is also potentially the case for the samples subjected to consolidation testing and as such the results presented in Appendix G should be regarded as providing a preliminary indication of consolidation parameters of the soils.

8.1.5 Standard/Cone Penetration Tests (SPT/CPT) 'N' Values - Relative Density

15 No. SPTs/CPTs were undertaken in the granular soils of the River Terrace Deposits, which recorded 'N' values from 2 to 35 corresponding to a relative density of very loose to medium dense at depths of 1.00m to 3.00m. The data is shown in Graph 2 (Appendix G).

8.1.6 Plasticity Indices (PI)

The Modified Plasticity Indices and Volume Change Potential of the natural clay are presented in Table 7 below in accordance with NHBC Standards Chapter 4.2.

Table 7. Volume Change Potential

Location / Depth (m)	Strata#	Plasticity Index (%)	Fraction <0.425mm (%)	Modified Plasticity Index* (%)	Volume Change Potential
TP05 / 1.20	RTD	26	98	26	Medium
TP10 / 1.20	RTD	17	100	17	Low
TP14 / 1.00	RTD	18	98	18	Low
TP20 / 1.20	RTD	14	99	14	Low
TP21 / 1.00	RTD	29	100	29	Medium
TP23 / 1.00	RTD	17	94	16	Low
TP24 / 1.00	RTD	22	100	22	Medium
TP27 / 1.00	RTD	13	100	13	Low
TP30 / 1.00	RTD	18	100	18	Low
TP39 / 1.00	RTD	14	100	14	Low

Notes: *Modified Plasticity Index = Plasticity Index x (% <0.425mm/100)
#RTD=River Terrace Deposits

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8.1.7 *Preliminary Equilibrium CBR Results from Plasticity Indices*

In addition to the in situ CBR testing (Section 6.1.7), preliminary equilibrium CBR values have been determined based on plasticity index tests (undertaken for foundations) in accordance with HA Interim Advice Note 73/06, to determine long term values. These are presented below in Table 8. It is acknowledged that sample depths are slightly deeper than those anticipated for road pavement.

Table 8. Preliminary Equilibrium CBR Values %.

Location / Depth (m)	Strata*	Plasticity Index (%)	Equivalent CBR Value %
TP05 / 1.20	RTD	26	3.0-4.0
TP10 / 1.20	RTD	17	4.0
TP14 / 1.00	RTD	18	4.0
TP20 / 1.20	RTD	14	3.0-4.0
TP21 / 1.00	RTD	29	3.0
TP23 / 1.00	RTD	17	4.0
TP24 / 1.00	RTD	22	4.0
TP27 / 1.00	RTD	13	3.0-4.0
TP30 / 1.00	RTD	18	4.0
TP39 / 1.00	RTD	14	3.0-4.0

*RTD = River Terrace Deposits

8.1.8 *Proposed Development*

As previously described, it is understood that the site is proposed for residential development.

8.2 Foundations

8.2.1 *Geotechnical Constraints*

The following potential geotechnical constraints have been identified:

- Softened or low density horizons were encountered in the majority of the exploratory holes (with the exception of WS08, TP09 TP16, TP38 & TP39) with apparent random variably throughout the soil profile from depths of 0.30m to >4.00m.
- Local softening in the London Clay in the southernmost section of the site in 3 No. exploratory holes from depths of 1.80-3.20m.
- Shallow groundwater encountered across the site at depths of 1.20m to 3.00m during the intrusive investigation as slow to moderate (and occasionally fast) inflows, and from depths of 0.00m to 3.10m during the subsequent initial monitoring visit.
- The majority of trial pit excavations encountered instability of the sides at depths of 2.00m to 4.00m (and occasionally from 1.00m).

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- Potential desiccation of the cohesive strata with respect to existing trees.
- Potentially presence of disseminated pyrite associated with the London Clay Formation.

8.2.2 Anticipated Foundation Types

The principal geotechnical constraint with respect to foundations is the presence of identified random softened/low density horizons across the site and also potential random softened/low density horizons remaining undetected beneath shallow foundations, resulting in unacceptable differential settlements structures.

As such, the use of piled foundations are considered likely to be the preferred foundation option for the site. Driven piles, approximately 4-5m in length, are anticipated to be the most cost effective solution, however, other systems may be suitable such as vibro concrete columns. Consequently, it is recommended that a specialist piling contractor is contacted to provide the design and warranty of a suitable foundation solution for the site.

Subject to additional investigation on a plot specific basis, traditional strip / trench fill foundations may locally be suitable; however, deepening of foundations is likely to be problematic due to anticipated excavation instability and the presence of shallow groundwater potentially reducing bearing capacities.

Raft foundations are not recommended at this stage (without further investigation and assessment) due to anticipated unacceptable differential settlements.

Vibro-stone columns are not considered suitable based on the presence of soft strata.

Ground improvement techniques such as lime stabilisation could potentially be undertaken to allow shallow/raft foundations to be used. However, the use of relatively short driven piles is considered likely to be more cost effective.

If piled foundations are adopted further investigation utilising deeper cable percussive boreholes will be required for pile design.

8.2.3 Floor Slabs

Suspended floor slabs are recommended for the site based on the variable ground conditions.

8.3 Chemical Attack on Buried Concrete

On the basis of the maximum soil soluble sulphate concentration for the River Terrace Deposits on the site of 1.16 g/l (1160 mg/l), and most acidic pH of 7.2 (excluding the topsoil which is to be stripped), ACEC Class AC-2 (Design Class DS-2) conditions are indicated to prevail on site as defined in BRE Special Digest 1 (2005) for foundations, based on natural ground and mobile groundwater conditions.

Additional testing of the London Clay Formation is recommended for the BRE SD1 (2005) suite due to the potential presence of pyritic sulphate.

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8.4 Flooding

The majority of the site lies within Flood Zone 1 and hence has a low probability of flooding However, the land adjacent to the west of the site in the vicinity of Rookery Cottage is located within Flood Zone 3, with the smallest portion of Flood Zone 2 potentially overlapping the westernmost tip of the northern site section.

8.5 Underground Plastic Services

Special precautions with respect to the protection of underground plastic water mains are not considered necessary for this site.

8.6 Slope Stability and Retaining Walls

Slope stability is not considered an issue on this site.

Any proposed retaining walls would need to be designed by a suitably experienced engineer.

8.7 Earthworks

Recorded maximum dry densities, optimum moisture contents and natural moisture contents ranged from 1.74-1.83 Mg/m^3, 13-15% and 18-26% respectively (Appendix G). Optimum moisture contents were typically significantly below the natural moisture contents indicating the anticipated requirement for control of moisture contents during any earthworks.

8.8 Fault Reactivation

No significant faults are indicated on the site.

8.9 Excavations

Dewatering of excavations is anticipated to deal with perched pockets of groundwater and during periods of heavy precipitation or if excavations are to remain open for prolonged periods.

In general shallow excavations are likely to be stable for short periods of time. However, in deeper excavations and/or where shallow groundwater is encountered, excavations are likely to be less stable and will locally require shoring; particularly where excavations extend beyond 1.20m depth. In accordance with current Health and Safety Requirements, shoring or battering back of excavations is required in all cases where access for personnel is required into those excavations whenever there is a risk that collapse of the excavation could occur.

8.10 Road Pavement Design

Recorded in-situ CBR values ranged from 1.0% to 7.8%, and preliminary equilibrium CBR values of 2.5% to 4.0% were indicated based on Atterberg Limit testing (albeit for slightly deeper strata). Consequently, a CBR design value of between <2% and 4.0% is recommended for the cohesive soils and geotechnically suitable Made Ground depending on localised conditions. Further Atterberg Limit testing of the cohesive soils at formation level is recommended to confirm this. A CBR design value of 20% is recommended for localised granular soils.

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8.11 Loose/Soft Spots

The formation (of foundations, floor slabs and roads etc.) should be inspected for soft/loose spots by a suitably experienced geotechnical engineer. Soft spots if encountered should be removed and replaced with suitable well compacted granular material/lean mix concrete as deemed appropriate. Soft spots beneath roads may also require the use of additional geotextiles or geotechnical improvement with lime/cement. Any loose soils at formation level may need to be proof rolled to increase the relative density.

8.12 Soakaways

As previously described, it was not possible to calculate soil infiltration rates in the natural strata due to the absence of significant infiltration, which was consistent with the predominantly cohesive strata and shallow groundwater encountered.

9. ENVIRONMENTAL CONCLUSIONS & RECOMMENDATIONS

Following the findings of the intrusive investigation and generic quantitative risk assessment, the preliminary conceptual site model has been revised as detailed below in Sections 9.1.1 and 9.1.2 and as illustrated in Figures 5A and 5B of Appendix A.

9.1 Revised Conceptual Model

9.1.1 Revised Human Health Conceptual Model

Identified Sources: No significant contamination has been identified in the natural ground for the proposed residential end use.

Potential Risks: End users of the site and construction/maintenance workers are therefore not considered to be at significant risk from the site as no significant contaminant sources have been identified by the chemical analyses undertaken to date.

9.1.2 Revised Controlled Waters Conceptual Model

Potential Sources: No significant soil sources have been identified.

Potential Risks: Risks to Controlled Waters are unlikely to be significant based on the information available.

9.2 Ground Gases

According to the preliminary gas monitoring results, the site is potentially characterised as NHBC 'Green'. However, further monitoring is recommended in particular in the north west near the off site landfill located 40m north west.

Furthermore, should any significant quantities of biodegradable materials be encountered during construction (backfilled ponds etc.), beneath the proposed properties, these should be removed and replaced with inert material.

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As previously described, the site is not in a Radon Affected Area; as such no protective radon measures are required.

9.3 Risks to Adjacent Land and Third Parties

The information available indicates that risks to adjacent land from the area investigated are not considered to be significant.

9.4 Risks from Adjacent Land and Third Parties

Risks from adjacent land are not considered to be significant based on the information available.

9.5 Potential Geo-Environmental Liabilities

Potential geo-environmental liabilities under Pt2A of the Environmental Protection Act (1990) and the Groundwater Regulations (GWR) 2009, relating to the site in its current are not anticipated to be significant.

9.6 Waste Classification

The chemical analysis results indicate that the strata is likely to be characterised as non-hazardous / inert waste. Therefore, excess arisings should be suitable for use as general fill on other development sites or taken to a suitable waste treatment centre based on this initial characterisation and the total soil analyses.

9.7 Re-Use of Topsoil

The chemical analysis undertaken indicates that the topsoil present on site is suitable for re-use.

9.8 Remediation

9.8.1 Human Health Remedial Measures

Based on the information available, no remedial measures are considered necessary to protect human health.

9.8.2 Protection of Controlled Waters

No remedial measures are considered necessary to protect Controlled Waters from the site itself, based on the information available.

9.8.3 Unidentified Contamination

GEG should be contacted if any gross contamination is encountered as part of the works, with a view to its assessment and removal.

9.8.4 Unidentified Underground Structures

GEG should be contacted if any underground structures are encountered such as tanks or wells to determine further requirements.

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9.9 Further Investigation

The following further work is recommended:

- Deeper cable percussive boreholes for pile design purposes.
- Additional testing of the London Clay Formation due to the potential presence of pyritic sulphate.
- Further gas monitoring is recommended in particular in the north west near the off site landfill.

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11. LIMITATIONS

As with all intrusive site investigations, there is a possibility that localised contamination 'hot spots'/geotechnical features remain undetected on the site. Therefore, as with standard practices, this report does not provide a warranty to cover limited localised contamination 'hot spots'/geotechnical features or any post-investigation importation of contamination.

The conclusions and recommendations stated herein are based on information available at the time of production. These may not necessarily apply if the site is to be utilised for a more or less sensitive purpose in the future, or if operational procedures or management alter over time.

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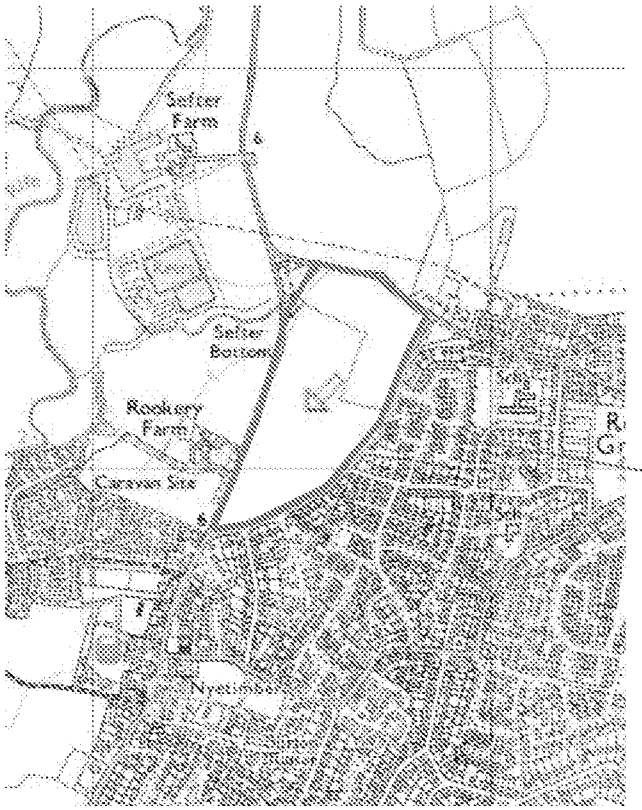
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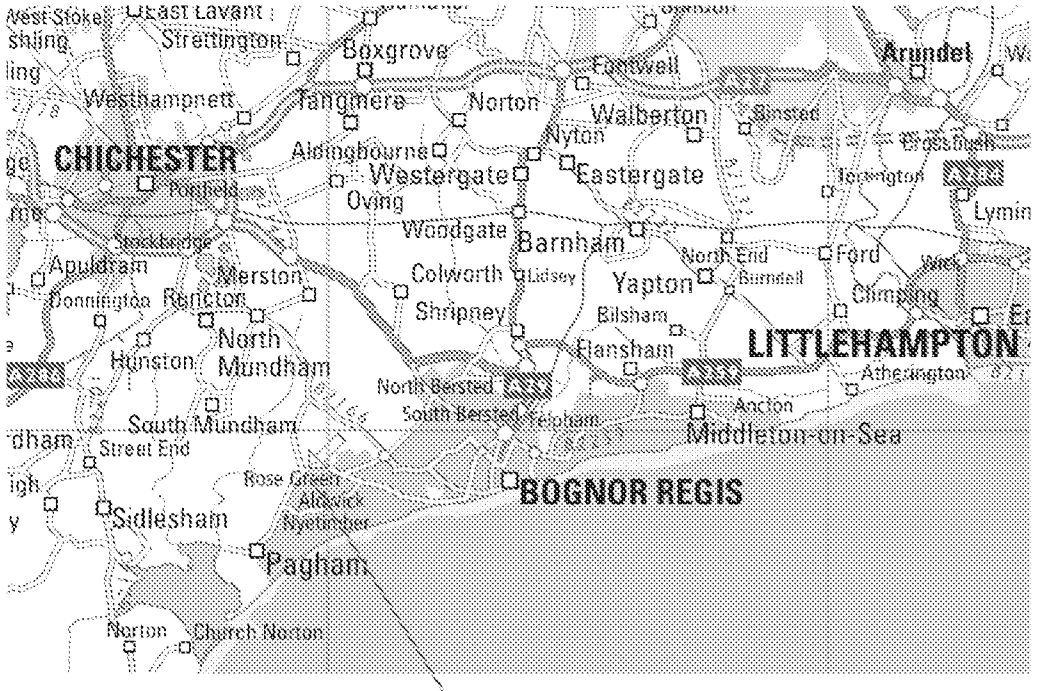
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APPENDIX A

FIGURES AND PLANS

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SITE LOCATION

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TITLE: FIGURE 1: SITE LOCATION PLAN	**CLIENT:** BROOKBANKS / HLM		**DRAWN/CHECKED:** JM / MP		GEG House, 17 Graham Road Malvern, WR14 2HR Tel. 01684 212526 Fax 01684 576917 admin@g-eg.co.uk, www.g-eg.co.uk Geo Environmental Group
SITE: HOOK LANE, PAGHAM	**PROJECT No.:** GEG-19-623	**SCALE:** NTS	**DATE:** 20/11/19	**REVISION:** A	

LEGEND



NOTES:

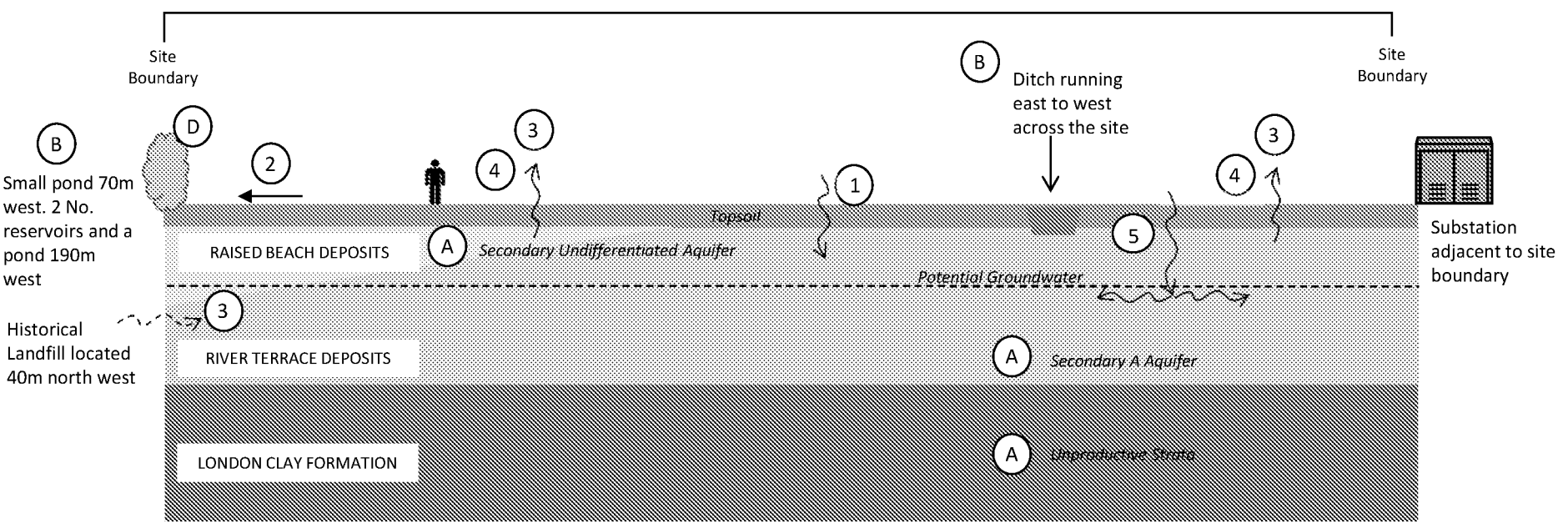
1. BASE IMAGE PROVIDED BY BROOKBANKS CONSULTING.

2. DRAWING TO BE USED IN CONJUCTION WITH GEG REPORT GEG-19-623/PI_PII.

JOB NUMBER: GEG-19-623				
PROJECT TITLE: HOOK LANE, PAGHAM				Geo Environmental Group
DRAWING TITLE: FIGURE 2: CURRENT LAYOUT PLAN			DRAWING NO.: GEG-19-623_003	
CLIENT: BROOKBANKS CONSULTING	REVISION NO.: A	ORIGINAL SIZE: A3	DIMENSIONS: METRES	SCALE: AS SHOWN
DRAWN BY: NN	CHECKED BY: MP	APPROVED BY: MR	ISSUE: FINAL ISSUE	DATE: 20/11/19

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PATHWAYS

1. Infiltration of precipitation
2. Surface water run off
3. Migration of ground gases (methane and carbon dioxide)
4. Potential dermal contact, ingestion of contaminated soil and/or dust and inhalation of gases/vapours
5. Potential leaching/mobilisation of contaminants and lateral and vertical migration

RECEPTORS

- Site users
- A — Aquifer type
- B — Watercourse
- C — Building Materials (Not applicable)
- D — Flora and fauna

SIGNIFICANT SOURCES

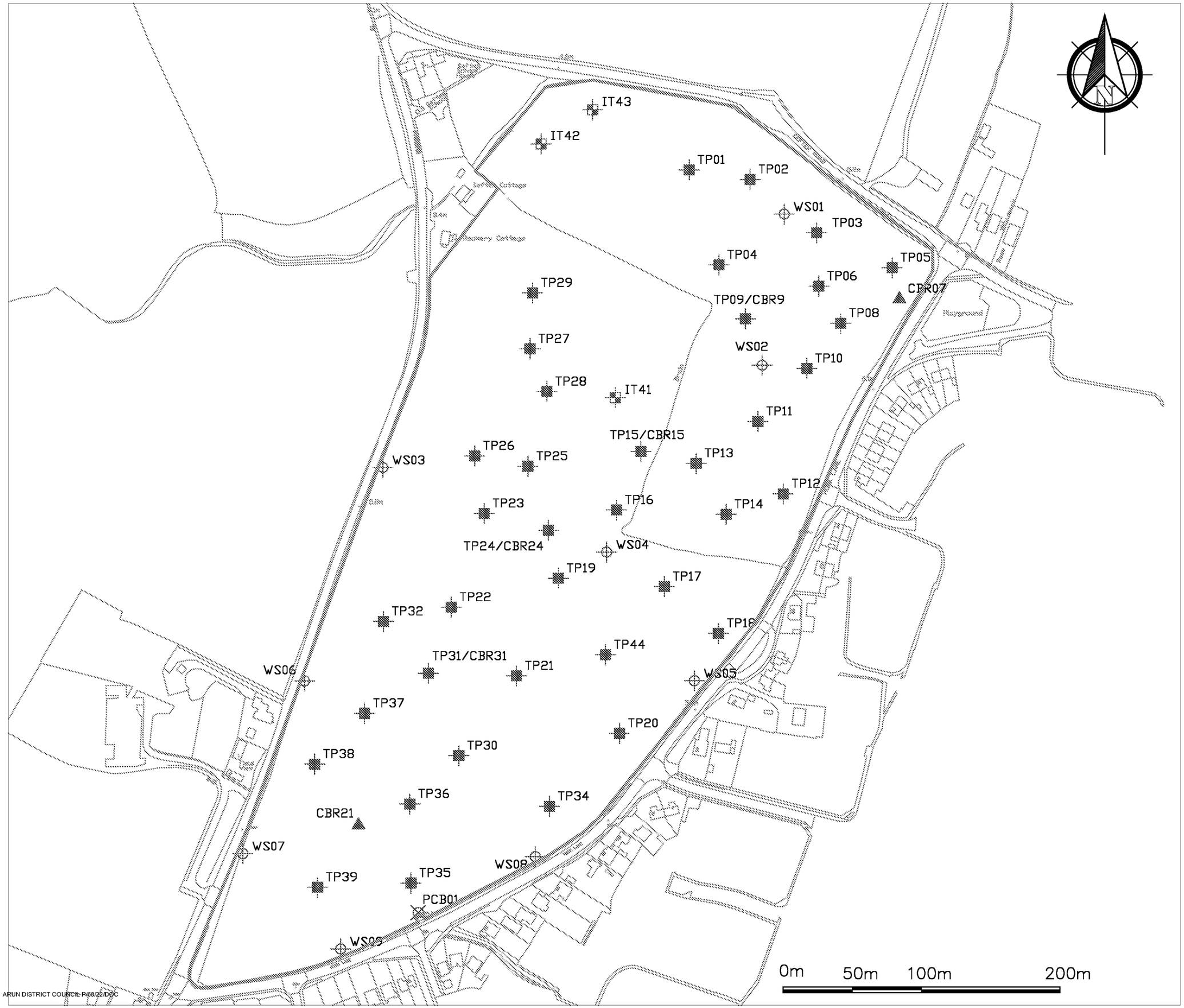
Potential sources of contamination associated with historical/current site usage (see text)

Please refer to the text of the report for further information relating to this diagram.

TITLE: FIGURE 3: PRELIMINARY CONCEPTUAL SITE MODEL	
SITE: HOOK LANE, PAGHAM	
CLIENT: BROOKBANKS / HLM	
PROJECT No.: GEG-19-623	**DRAWN/CHECKED:** NN / MP
SCALE: NTS	**DATE:** 03/12/19

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LEGEND

- TP01 — GEG TRIAL PIT LOCATION
- CBR1 — GEG CBR TEST LOCATION
- WS01 — GEG WINDOW SAMPLE LOCATION
- IT01 — GEG INFILTRATION TEST LOCATION
- PCB01 — GEG HAND DUG SURFACE SAMPLE

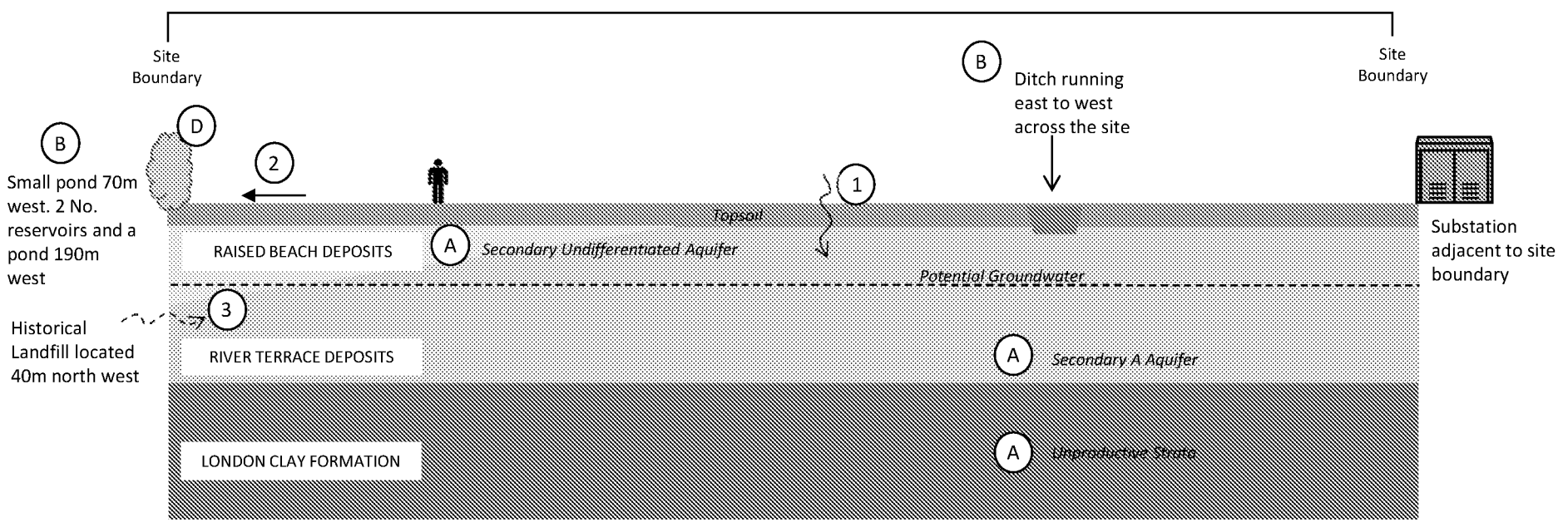
NOTES:

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JOB NUMBER: GEG-19-623				
PROJECT TITLE: HOOK LANE, PAGHAM				Geo Environmental Group
DRAWING TITLE: FIGURE 4: EXPLORATORY HOLE LOCATION PLAN			DRAWING NO: GEG-19-623_002	
CLIENT: BROOKBANKS CONSULTING	REVISION NO: A	ORIGINAL SIZE: A3	DIMENSIONS: METRES	SCALE: AS SHOWN
DRAWN BY: NN	CHECKED BY: MP	APPROVED BY: MR	ISSUE: FINAL ISSUE	DATE: 18/11/19

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PATHWAYS

1. Infiltration of precipitation
2. Surface water run off
3. Migration of ground gases (methane and carbon dioxide)
4. Potential dermal contact, ingestion of contaminated soil and/or dust and inhalation of gases/vapours
5. Potential leaching/mobilisation of contaminants and lateral and vertical migration

RECEPTORS

- Site users
- A — Aquifer type
- B — Watercourse
- C — Building Materials (Not applicable)
- D — Flora and fauna

SIGNIFICANT SOURCES

No significant sources of contamination have been identified to date associated with historical/current site usage.

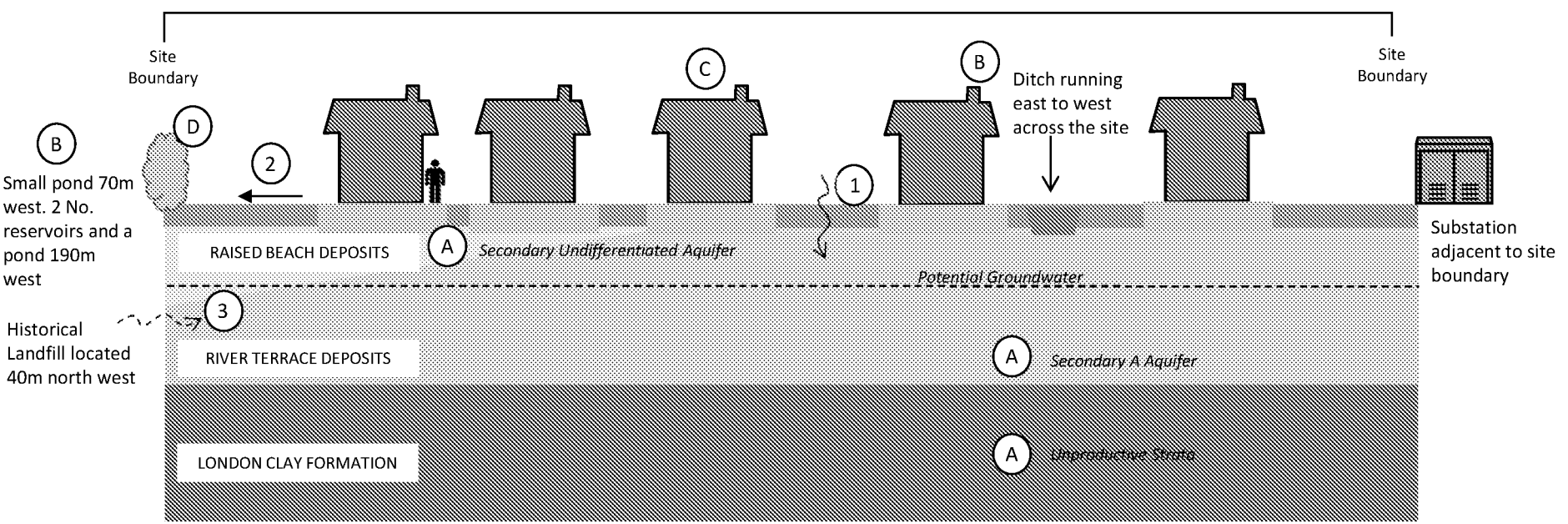
Please refer to the text of the report for further information relating to this diagram.

TITLE: FIGURE 5A: CONCEPTUAL SITE MODEL (EXISTING)	
SITE: HOOK LANE, PAGHAM	
CLIENT: BROOKBANKS / HLM	
PROJECT No.: GEG-19-623	**DRAWN/CHECKED:** NN / MP
SCALE: NTS	**DATE:** 03/12/19

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PATHWAYS

1. Infiltration of precipitation
2. Surface water run off
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5. Potential leaching/mobilisation of contaminants and lateral and vertical migration

RECEPTORS

- Site users
- A — Aquifer type
- B — Watercourse
- C — Building Materials (Not applicable)
- D — Flora and fauna

SIGNIFICANT SOURCES

No significant sources of contamination have been identified to date associated with historical/current site usage.

Please refer to the text of the report for further information relating to this diagram.

TITLE: FIGURE 5B: CONCEPTUAL SITE MODEL (PROPOSED)	
SITE: HOOK LANE, PAGHAM	
CLIENT: BROOKBANKS / HLM	
PROJECT No.: GEG-19-623	**DRAWN/CHECKED:** NN / MP
SCALE: NTS	**DATE:** 03/12/19

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APPENDIX B

PHOTOGRAPHIC RECORD

SITE WALKOVER

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Photo 1: View east across northern section of the site.



Photo 2: View south west across northern section of the site.



Photo 3: View south across northern section of the site.



Photo 4: View south across western section of the site.

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Photo 5: View east across central section of the site.



Photo 6: View south west across central section of the site.



Photo 7: View south across the site.



Photo 8: View south across the site.

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TRIAL PITTING

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Photo 1: Excavation of trial pit TP01.



Photo 2: Arisings from trial pit TP01.

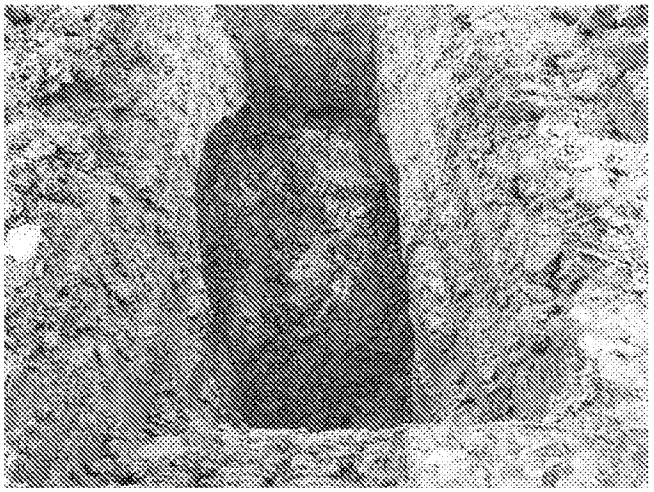


Photo 3: Excavation of trial pit TP02.



Photo 4: Arisings from trial pit TP02.

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Photo 5: Excavation of trial pit TP03.



Photo 6: Arisings from trial pit TP03.

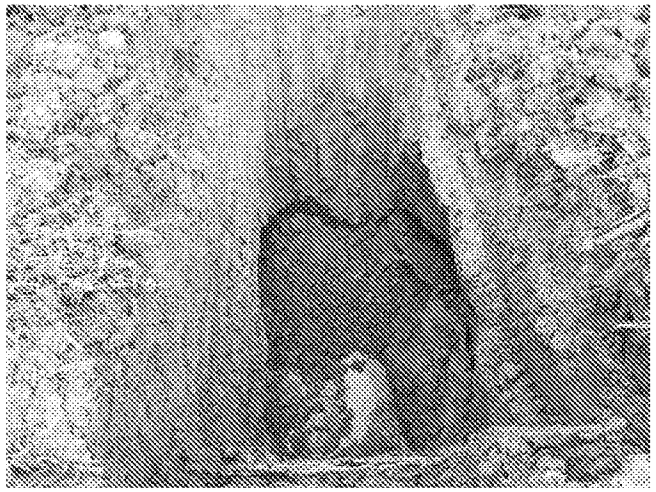


Photo 7: Excavation of trial pit TP04.



Photo 8: Arisings from trial pit TP04.

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Photo 9: Excavation of trial pit TP05.

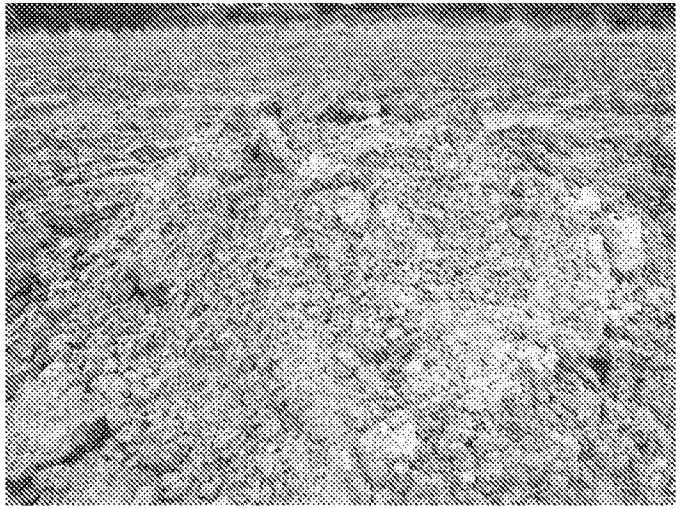


Photo 10: Arisings from trial pit TP05.

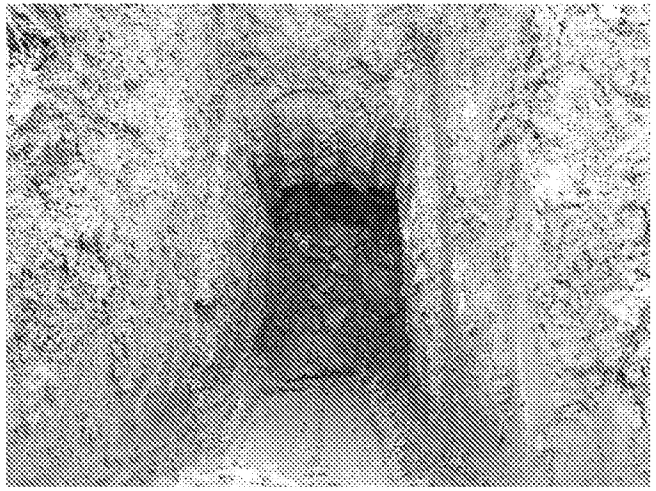


Photo 11: Excavation of trial pit TP06.

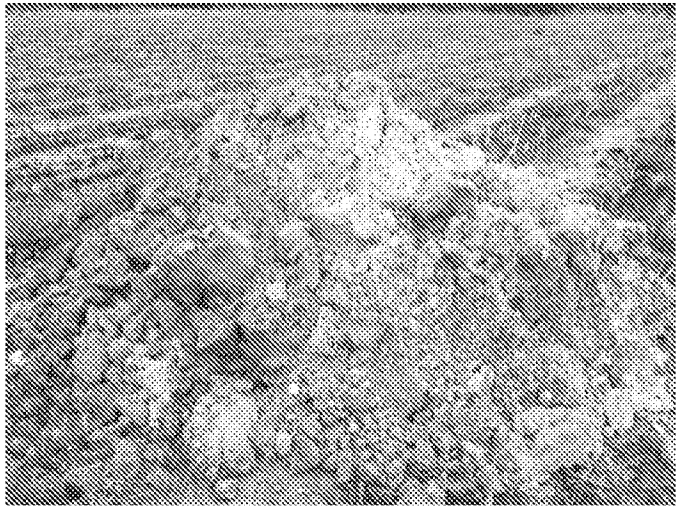


Photo 12: Arisings from trial pit TP06.

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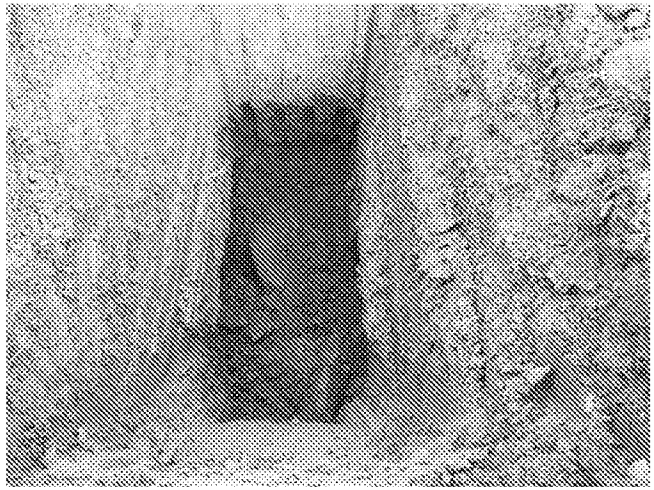


Photo 13: Excavation of trial pit TP08.



Photo 14: Arisings from trial pit TP08.

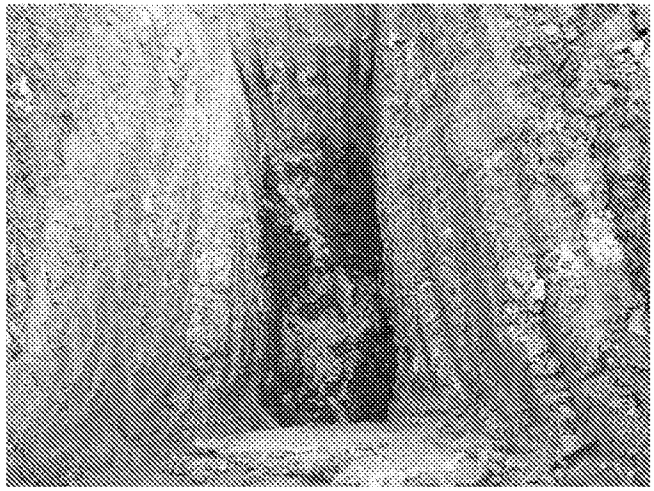


Photo 15: Excavation of trial pit TP09.

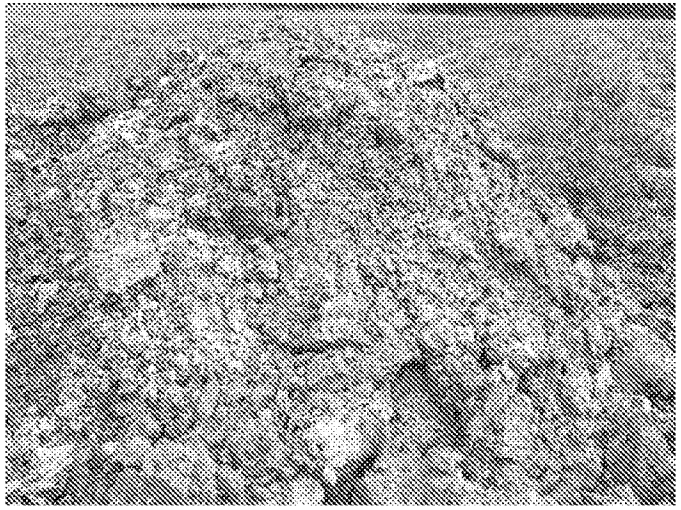


Photo 16: Arisings from trial pit TP09.

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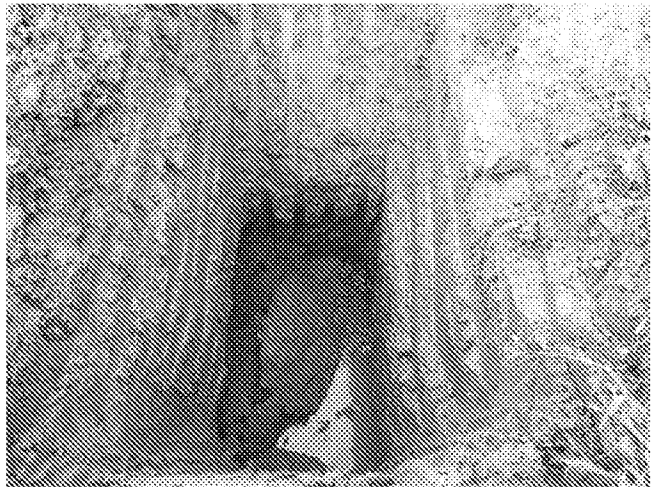


Photo 17: Excavation of trial pit TP10.



Photo 18: Arisings from trial pit TP10.

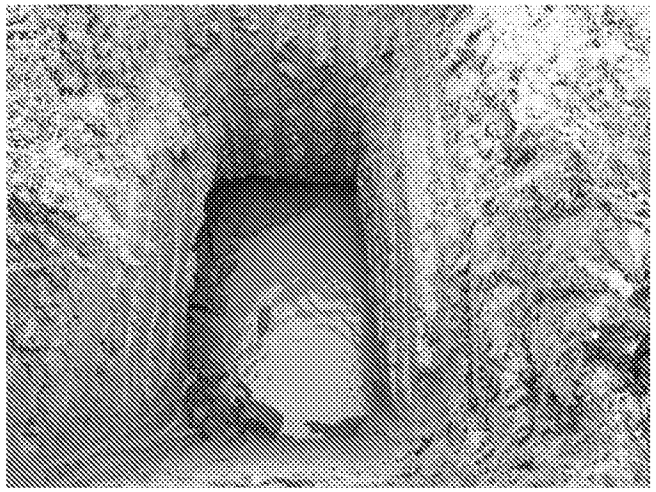


Photo 19: Excavation of trial pit TP11.

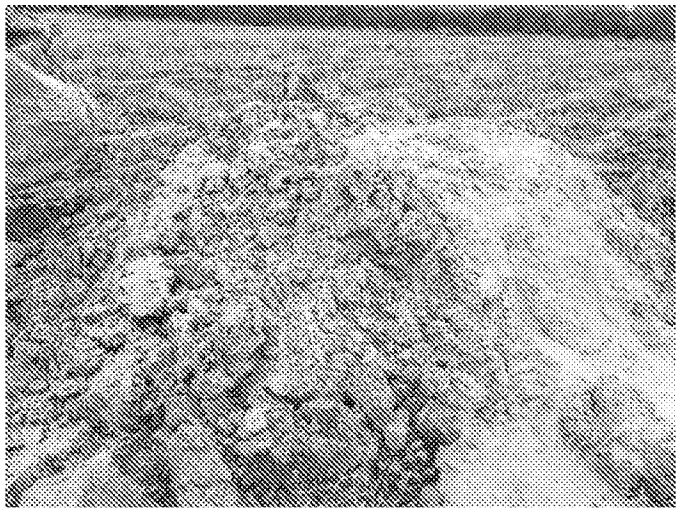


Photo 20: Arisings from trial pit TP11.

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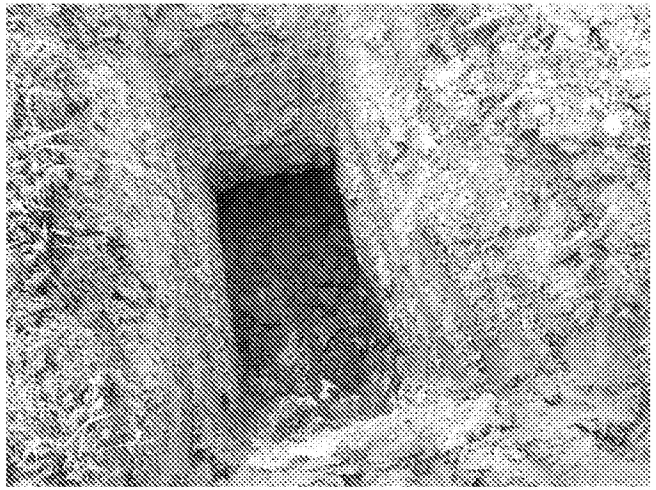


Photo 21: Excavation of trial pit TP12.



Photo 22: Arisings from trial pit TP12.



Photo 23: Excavation of trial pit TP13.



Photo 24: Arisings from trial pit TP13.

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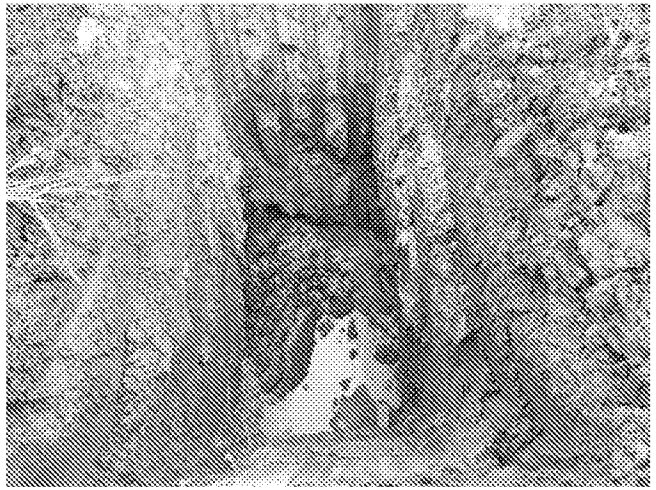


Photo 25: Excavation of trial pit TP14.

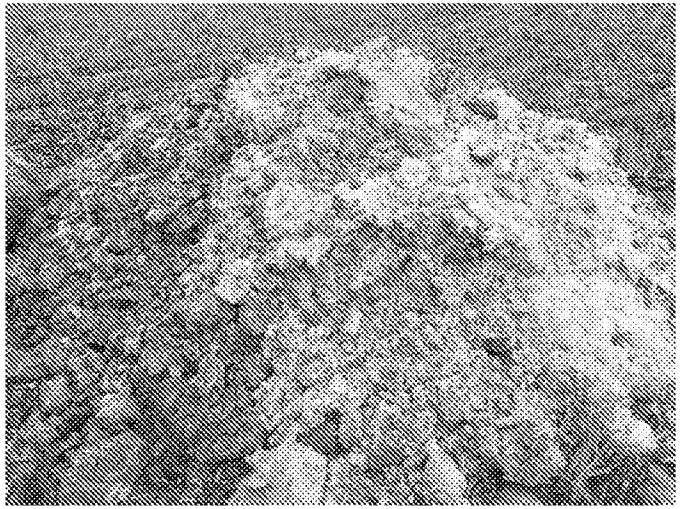


Photo 26: Arisings from trial pit TP14.

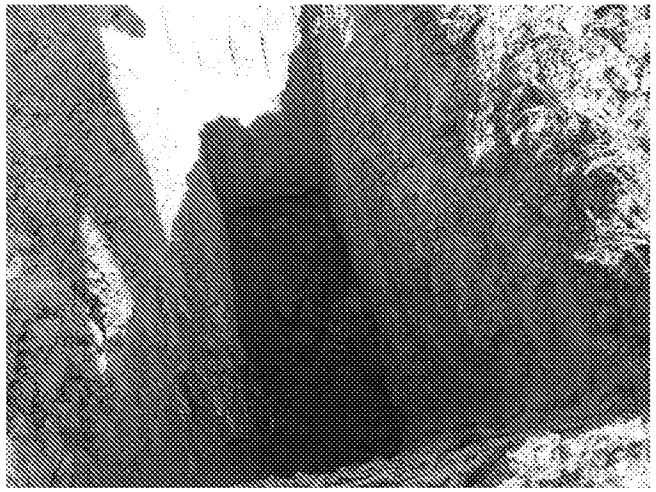


Photo 27: Excavation of trial pit TP15.



Photo 28: Arisings from trial pit TP15.

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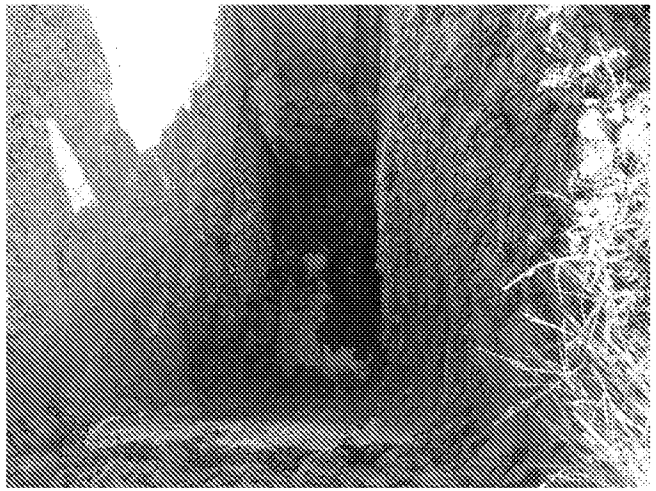


Photo 29: Excavation of trial pit TP16.



Photo 30: Arisings from trial pit TP16.

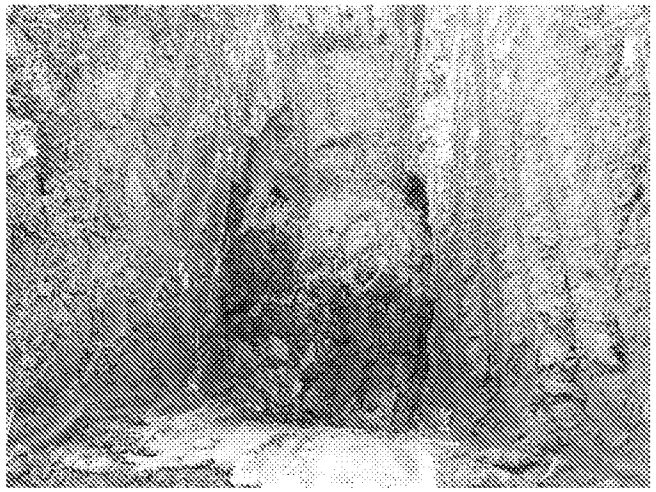


Photo 31: Excavation of trial pit TP17.



Photo 32: Arisings from trial pit TP17.

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Photo 33: Excavation of trial pit TP18.

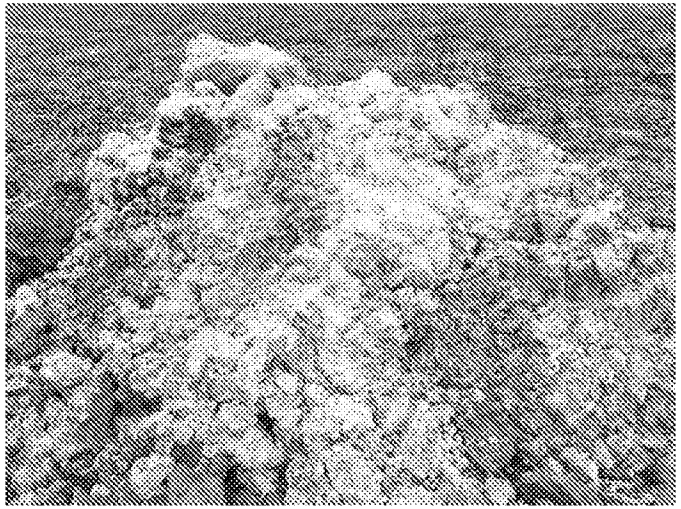


Photo 34: Arisings from trial pit TP18.

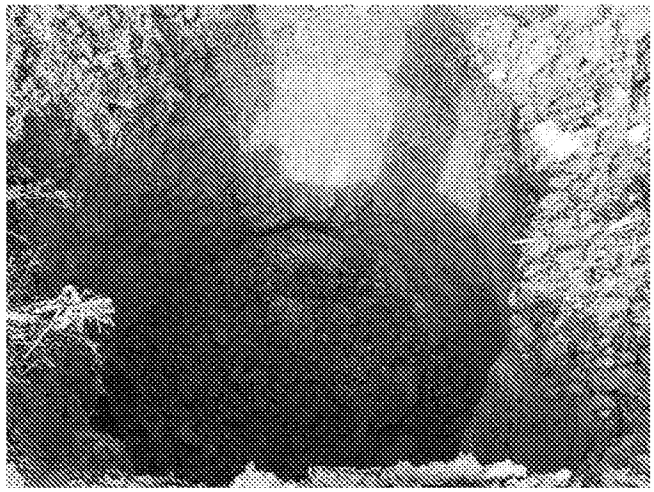


Photo 35: Excavation of trial pit TP19.

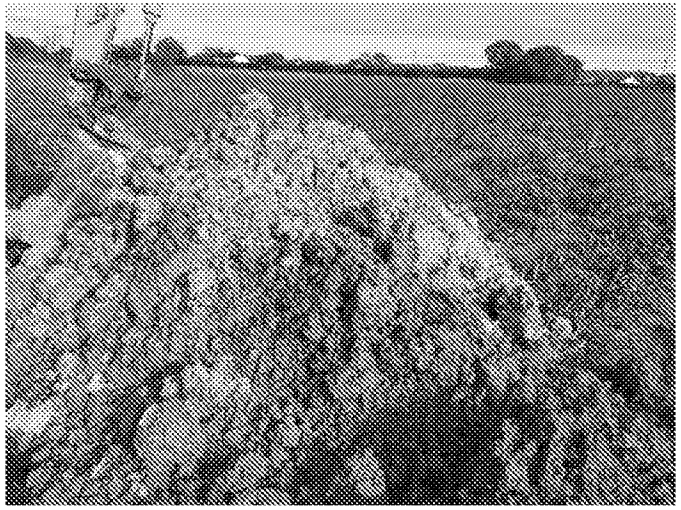


Photo 36: Arisings from trial pit TP19.

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Photo 37: Excavation of trial pit TP21.



Photo 38: Arisings from trial pit TP21.

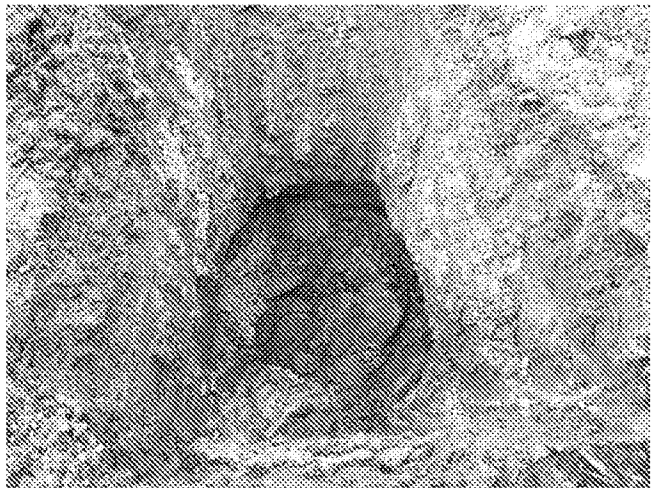


Photo 39: Excavation of trial pit TP22.



Photo 40: Arisings from trial pit TP22.

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Photo 41: Excavation of trial pit TP23.



Photo 42: Arisings from trial pit TP23.



Photo 43: Excavation of trial pit TP24.

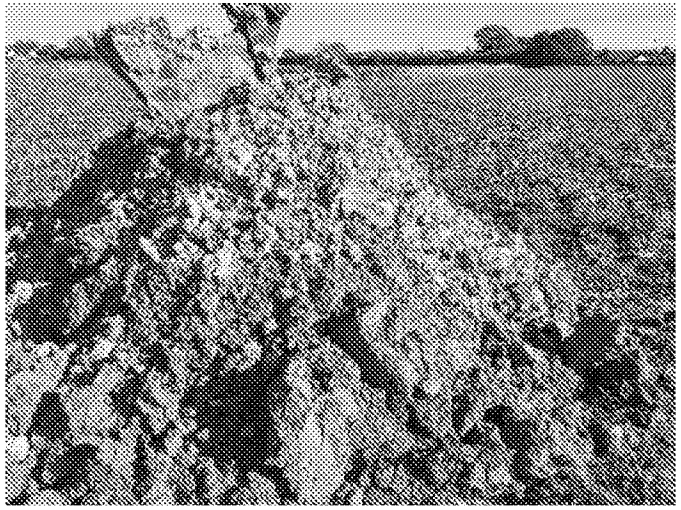


Photo 44: Arisings from trial pit TP24.

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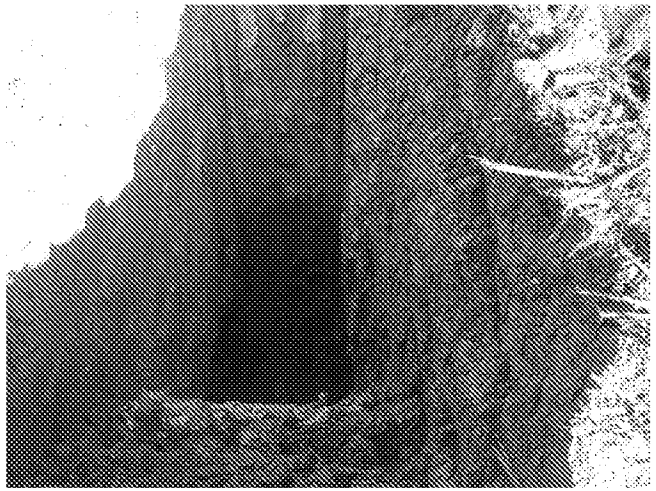


Photo 45: Excavation of trial pit TP25.



Photo 46: Arisings from trial pit TP25.



Photo 47: Excavation of trial pit TP26.

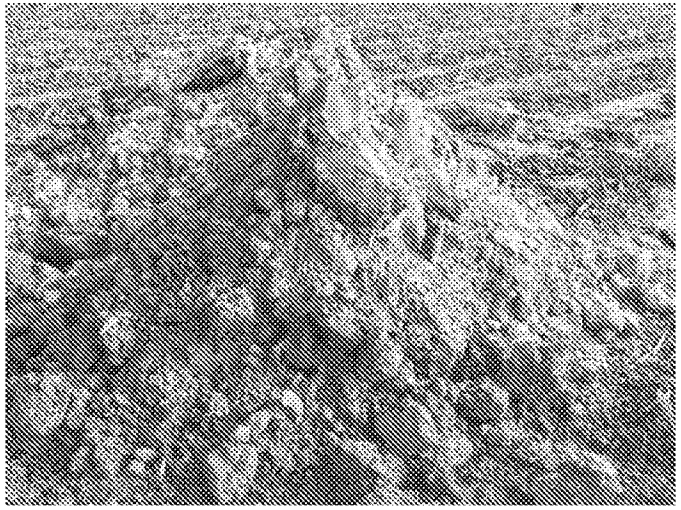


Photo 48: Arisings from trial pit TP26.

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Photo 49: Excavation of trial pit TP27.



Photo 50: Arisings from trial pit TP27.



Photo 51: Excavation of trial pit TP28.



Photo 52: Arisings from trial pit TP28.

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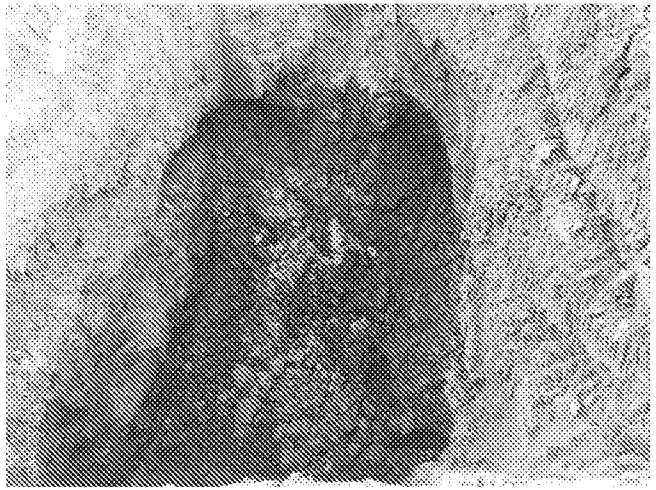


Photo 53: Excavation of trial pit TP29.



Photo 54: Arisings from trial pit TP29.



Photo 55: Excavation of trial pit TP30.



Photo 56: Arisings from trial pit TP30.

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Photo 57: Excavation of trial pit TP31.

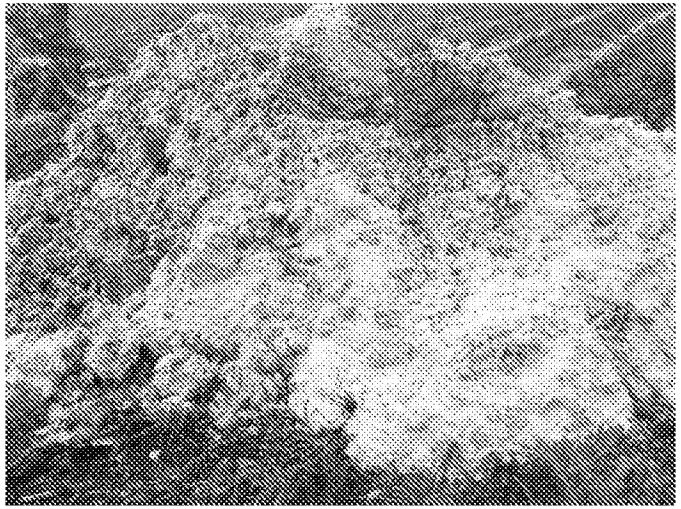


Photo 58: Arisings from trial pit TP31.



Photo 59: Excavation of trial pit TP32.



Photo 60: Arisings from trial pit TP32.

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Photo 61: Excavation of trial pit TP34.



Photo 62: Arisings from trial pit TP34.

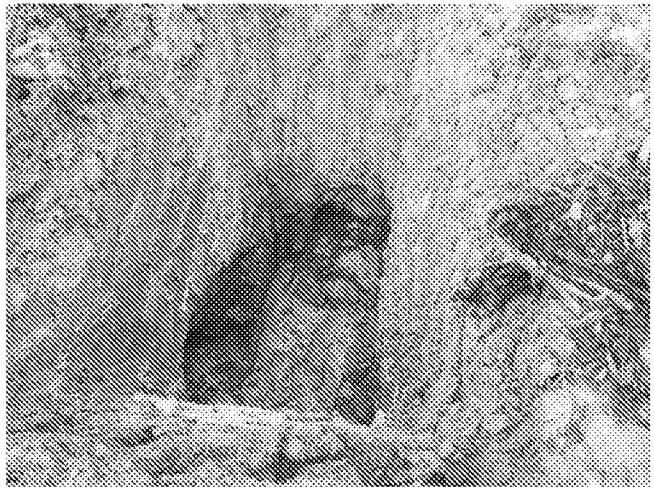


Photo 63: Excavation of trial pit TP35.



Photo 64: Arisings from trial pit TP35.

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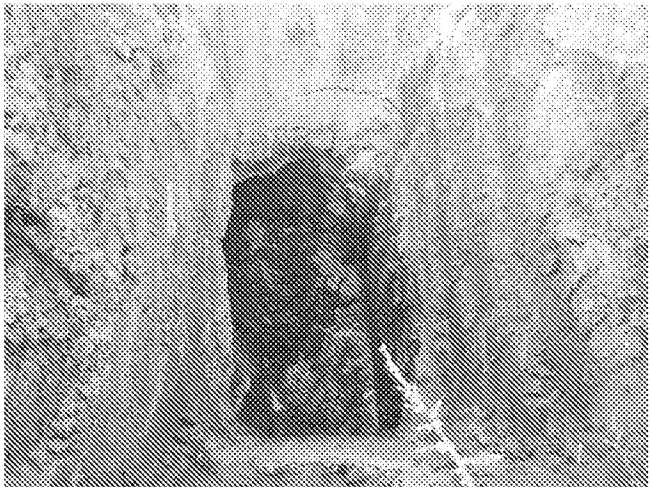


Photo 65: Excavation of trial pit TP36.



Photo 66: Arisings from trial pit TP36.



Photo 67: Excavation of trial pit TP37.



Photo 68: Arisings from trial pit TP37.

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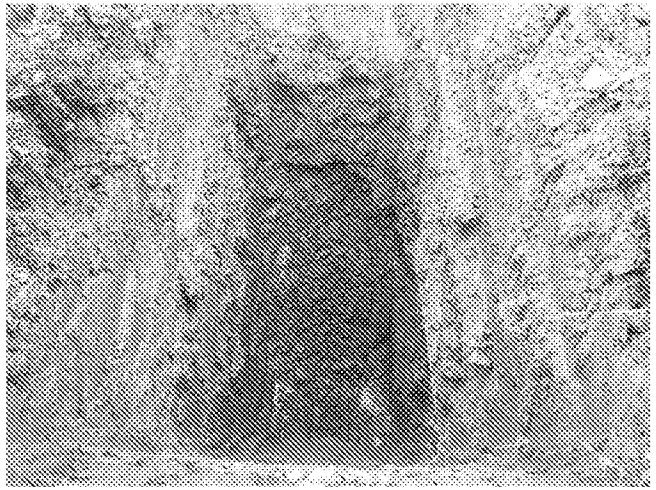


Photo 69: Excavation of trial pit TP38.

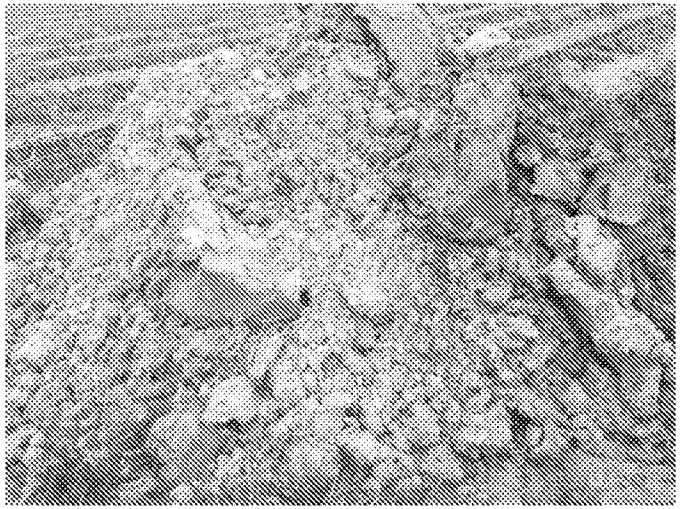


Photo 70: Arisings from trial pit TP38.

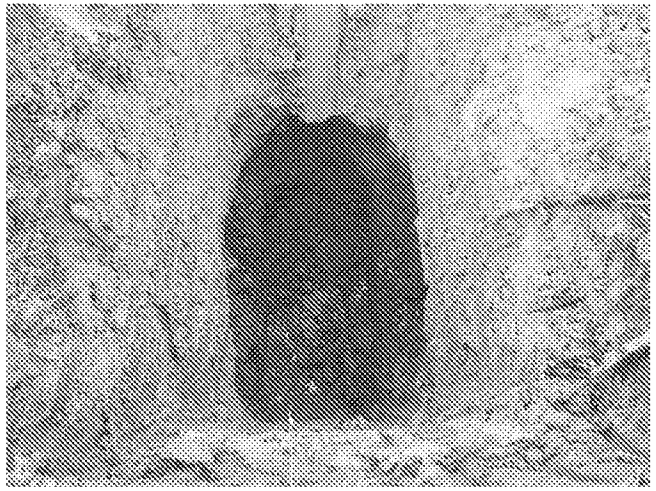


Photo 71: Excavation of trial pit TP39.



Photo 72: Arisings from trial pit TP39.

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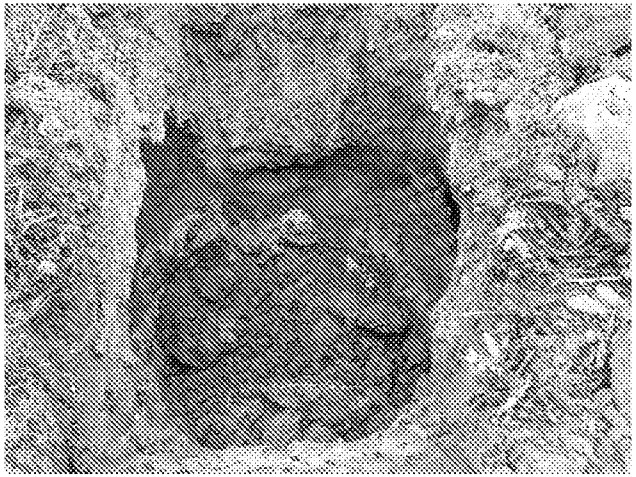


Photo 73: Excavation of trial pit TP44.



Photo 74: Arisings from trial pit TP44.

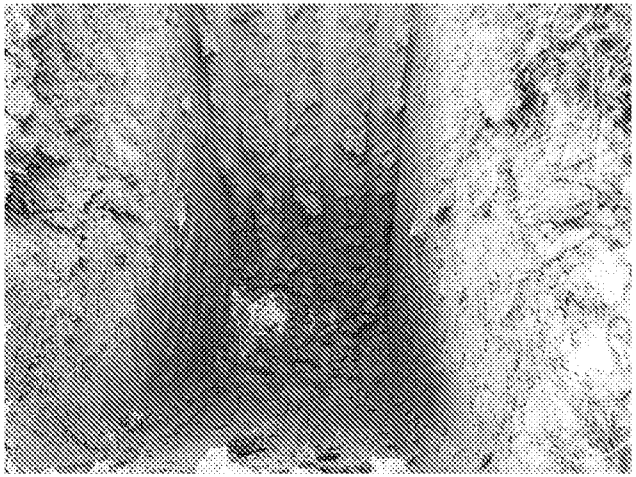


Photo 75: Excavation of trial pit IT41.

No Photograph

Photo 76: Arisings from trial pit IT41.

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Photo 77: Excavation of trial pit IT42.



Photo 78: Arisings from trial pit IT42.

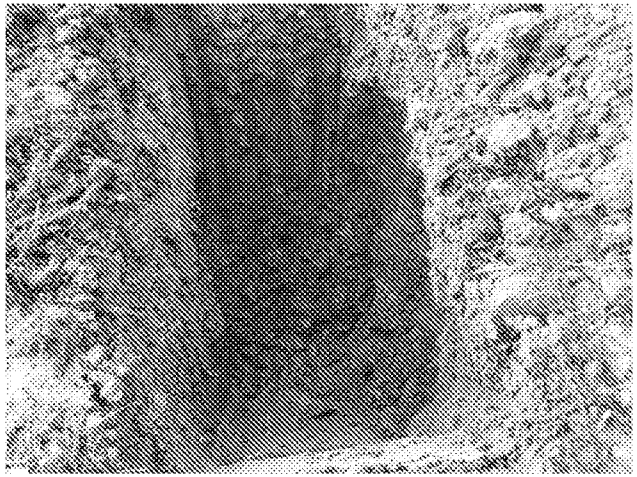


Photo 79: Excavation of trial pit IT43.



Photo 80: Arisings from trial pit IT43.

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APPENDIX C

EXPLORATORY HOLE LOGS

Borehole Log

Borehole No. **WS01**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489737E - 99402N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 23/10/2019	Logged By NN

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
		0.50		HVP=42	0.40			Firm orangish brown silty CLAY. (RIVER TERRACE DEPOSITS)
		1.00	SPT	N=6 (1,1/1,2,1,2)				*1.00-1.50m Becoming soft*
		1.50	PP	0.00	1.50			(Soft to very soft) sandy slightly gravelly silty CLAY. Gravel is fine to medium sub-angular flint. (RIVER TERRACE DEPOSITS)
		2.00	SPT	N=30 (2,3/5,7,8,10)	2.00			Medium dense to dense yellowish brown gravelly medium SAND. Gravel is medium sub-rounded flint. (RIVER TERRACE DEPOSITS)
								2.50-3.40m Becoming grey
		3.00	SPT	N=4 (1,1/1,1,1,1)				*3.00-3.40m Becoming very loose to loose*
					3.40			(Stiff) pinkish brown CLAY. (LONDON CLAY FORMATION)
					3.70			Stiff dark grey silty CLAY. (LONDON CLAY FORMATION)
		4.00	SPT	N=23 (2,3/4,5,7,7)				
		5.00 - 5.50	U					
					5.50			End of Borehole at 5.500m

Remarks

1. No groundwater encountered. 2. HVP=Uncorrected Hand Vane Measurement. 3. PP = Pocket Penetrometer measurement in kPa. 4. 50mm standpipe installed 5m, response zone 5-1m, bentonite seal 1-0.3m, flush cover concreted 0.3-0m.

Borehole Log

Borehole No. **WS02**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489725E - 99297N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 23/10/2019	Logged By NN

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.50			Very soft to soft greyish brown silty CLAY. (RIVER TERRACE DEPOSITS)
		0.80		HVP=20				*0.80-2.00m Becoming soft*
		1.00	SPT	N=5 (1,0/1,1,1,2)				
		2.00	SPT	N=4 (1,2/1,1,1,1)	2.00			Very loose to loose yellowish brown silty coarse SAND & GRAVEL of medium sub-rounded flint and quartzite. (RIVER TERRACE DEPOSITS)
		3.00	SPT	N=7 (1,1/1,2,2,2)				*3.00-4.00m Becoming loose*
		4.00	SPT	N=12 (2,1/2,3,3,4)	4.00			Firm pinkish brown CLAY. (LONDON CLAY FORMATION)
					4.80			(Stiff) dark grey CLAY. (LONDON CLAY FORMATION)
					5.00			End of Borehole at 5.000m

Remarks

1. No groundwater encountered. 2. HVP=Uncorrected Hand Vane Measurement. 3. Upon completion borehole backfilled with arisings.

Borehole Log

Borehole No. **WS03**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489450E - 99223N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 23/10/2019	Logged By NN

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.40			(Soft) dark brown slightly sandy silty CLAY. (RIVER TERRACE DEPOSITS)
		0.80		HVP=18				*0.80-1.00m Becoming very soft*
		1.00	SPT	N=4 (1,1/1,1,1,1)				*1.00-1.50m Becoming very soft to soft*
		1.50		HVP=24				*1.50-1.80m Becoming soft*
		1.80		HVP=8				*1.80-2.00m Becoming (very soft)*
		2.00	SPT	N=4 (2,2/1,1,1,1)	2.00			Very loose to loose GRANULAR SOILS. [Limited Recovery] (RIVER TERRACE DEPOSITS)
		2.80		HVP=94				
		3.00	SPT	N=7 (1,2/1,2,2,2)				*3.00-4.00m Becoming loose granular soil*
		4.00	SPT	N=14 (2,2/3,3,4,4)	4.00			Firm dark brown slightly sandy silty CLAY with lenses of sand and gravel. (RIVER TERRACE DEPOSITS)
					4.30			(Stiff) pinkish brown CLAY. (LONDON CLAY FORMATION)
					4.90			(Stiff) dark greyish brown CLAY. (LONDON CLAY FORMATION)
					5.00			End of Borehole at 5.000m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Remarks

1. No groundwater encountered. 2. HVP=Uncorrected Hand Vane Measurement. 3. Upon completion borehole backfilled with arisings.

Borehole Log

Borehole No. **WS04**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489612E - 99162N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 23/10/2019	Logged By NN

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.40			(Firm) reddish brown silty CLAY. (RIVER TERRACE DEPOSITS)
		0.80		HVP=22				*0.80-1.00m Becoming soft*
		1.00	SPT	N=10 (1,1/2,2,3,3)				*1.00-1.40m Becoming firm*
					1.40			(Soft) orangish brown sandy gravelly SILT. Gravel is fine sub-angular flint. (RIVER TERRACE DEPOSITS)
								1.80-2.00m Becoming (very soft)
		2.00	SPT	N=2 (1,1/1,0,0,1)	2.00			Very loose white medium SAND & GRAVEL of fine sub-angular flint and chalk. (RIVER TERRACE DEPOSITS)
		3.00	SPT	N=34 (3,5/7,9,9,9)				*3.00-3.50m Becoming dense*
					3.50			End of Borehole at 3.500m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Remarks

1. No groundwater encountered. 2. Sand and gravel jamming barrel at 2.00-3.50m. 3. HVP=Uncorrected Hand Vane Measurement. 4. Upon completion borehole backfilled with arisings.

Borehole Log

Borehole No. **WS05**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489673E - 99069N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 24/10/2019	Logged By NN

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.30			(Firm) yellowish brown silty CLAY. (RIVER TERRACE DEPOSITS)
		0.80		HVP=18				*0.60-2.00m Becoming very soft*
		1.00	SPT	N=1 (0,0/0,0,1,0)				
		1.40		HVP=4				
		2.00	SPT	N=11 (1,0/1,3,3,4)	2.00			Medium dense yellowish brown silty gravelly SAND. Gravel is fine sub-angular flint and chalk. (RIVER TERRACE DEPOSITS)
					2.50			(Soft to firm) reddish brown silty CLAY. (RIVER TERRACE DEPOSITS)
		3.00	SPT	N=11 (2,2/3,3,2,3)	3.00			Firm dark grey CLAY. (LONDON CLAY FORMATION)
		4.00	SPT	N=14 (1,2/3,3,4,4)				
					5.00			End of Borehole at 5.000m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Remarks

1. No groundwater encountered. 2. HVP=Uncorrected Hand Vane Measurement. 3. 50mm standpipe installed 5m, response zone 5-1m, bentonite seal 1-0.3m, flush cover concreted 0.3-0m.

Borehole Log

Borehole No. **WS06**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489393E - 99068N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 24/10/2019	Logged By

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.30			(Firm) brown silty CLAY. (RIVER TERRACE DEPOSITS)
		0.60		HVP=18				*0.60-0.80m Becoming very soft*
								0.80-1.45m Becoming firm to stiff
		1.00	SPT	N=15 (3,5/5,4,3,3)				
					1.45			(Very soft to soft) sandy slightly gravelly silty CLAY with occasional lenses of sand. Gravel is fine chalk and flint. (RIVER TERRACE DEPOSITS)
					1.90			Medium dense yellowish brown silty SAND & GRAVEL of fine to medium flint, chalk and quartzite. (RIVER TERRACE DEPOSITS)
		2.00	SPT	N=14 (3,4/5,4,3,2)				
		3.00	SPT	N=20 (3,3/2,5,6,7)				
					3.45			End of Borehole at 3.450m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Remarks

1. No groundwater encountered. 2. HVP=Uncorrected Hand Vane Measurement. 3. Upon completion borehole backfilled with arisings.

Borehole Log

Borehole No. **WS07**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489349E - 98944N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 24/10/2019	Logged By

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.40			(Firm) brown silty CLAY. (RIVER TERRACE DEPOSITS)
					0.80			(Soft) brown sandy gravelly silty CLAY. Gravel is medium sub-rounded flint. (RIVER TERRACE DEPOSITS)
		1.00	SPT	N=35 (4,5/8,10,8,9)	1.00			Dense greyish brown silt gravelly SAND. Gravel is fine sub-angular chalk and flint. (RIVER TERRACE DEPOSITS)
					1.80			Soft pinkish brown CLAY. (LONDON CLAY FORMATION)
		2.00	SPT	N=6 (2,1/2,1,1,2)				
					2.70			Firm dark grey silty CLAY. (LONDON CLAY FORMATION)
		3.00	SPT	N=13 (2,2/3,3,3,4)				
					3.45			End of Borehole at 3.450m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Remarks

1. No groundwater encountered. 2. Upon completion borehole backfilled with arisings.

Borehole Log

Borehole No. **WS08**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489560E - 98942N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates: 24/10/2019	Logged By

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
					0.30			(Firm) orangish brown silty CLAY. (RIVER TERRACE DEPOSITS)
								0.80-1.00m Becoming (soft)
		1.00	SPT	N=14 (1,2/3,3,4,4)	1.00			Firm brown and grey clayey SILT. (RIVER TERRACE DEPOSITS)
					1.50			Medium dense brown and orangish brown silty SAND & GRAVEL of fine sub-angular flint and chalk. (RIVER TERRACE DEPOSITS)
		2.00	SPT	N=27 (3,4/6,6,7,8)				
		3.00	SPT	N=20 (2,3/3,4,6,7)				
					3.70			(Stiff) dark grey silty CLAY. (LONDON CLAY FORMATION)
					4.00			End of Borehole at 4.000m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Remarks

1. No groundwater encountered. 2. Upon completion borehole backfilled with arisings.

Borehole Log

Borehole No. **WS09**

Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489419E - 98876N	Hole Type WS
Location: Hook Lane, Pagham, PO21 3PD		Level:	Scale 1:36
Client: Brookbanks / Hallam Land Management		Dates:	Logged By NN

Well	Water Strikes	Sample and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
		0.50 - 1.00	U		0.40			(Firm) orangish brown slightly gravelly silty CLAY. Gravel is medium sub-rounded flint. (RIVER TERRACE DEPOSITS)
		1.00	SPT	N=17 (2,2/3,3,5,6)				*1.00-1.50m Becoming stiff*
					1.50			(Soft) yellowish brown sandy clayey SILT. (RIVER TERRACE DEPOSITS)
		2.00	SPT	N=25 (5,7/8,6,6,5)	1.80			Medium dense yellowish brown silty gravelly SAND. Gravel is medium sub-rounded flint and quartzite. (RIVER TERRACE DEPOSITS)
					2.80			(Stiff) pinkish brown CLAY. (LONDON CLAY FORMATION)
		3.00	SPT	N=17 (3,4/7,4,3,3)	2.90			Stiff dark grey CLAY. (LONDON CLAY FORMATION)
		4.00	SPT	N=28 (2,4/6,7,8,7)				
		4.50 - 5.00	U					
					5.00			End of Borehole at 5.000m

Remarks

1. No groundwater encountered. 2. 50mm standpipe installed 4m, response zone 4-1m, bentonite seal 1-0.3m, flush cover concreted 0.3-0m.

Trial Pit Log

Geo Environmental Group

TrialPit No **IT41** Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489619.17 - 99273.30 Level:	Date 23/10/2019
Location: Hook Lane, Pagham, PO21 3PD		Dimensions (m): 2.00 × 0.90 Depth 2.00	Scale 1:25
Client: Brookbanks / Hallam Land Management			Logged NN

Water Strike	Samples & In Situ Testing Depth	Type	Results	Depth (m)	Level (m)	Legend	Stratum Description
				0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
				0.40			(Soft to firm) orangish brown slightly sandy silty CLAY. (RIVER TERRACE DEPOSITS)
	1.00	HVP	30				*1.00-1.50m Becoming soft*
	1.00	HVP	30				
	1.00	HVP	30				
				1.50			Loose slightly gravelly silty clayey fine to coarse SAND. Gravel is fine to medium. (RIVER TERRACE DEPOSITS)
▼	1.80	B					
				2.00			End of Pit at 2.000m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Remarks: 1. Groundwater encountered at 2.00m as very slow flow. 2. Infiltration test undertaken in trial pit. 3. HVP=Uncorrected Hand Vane Measurement. 4. Upon completion trial pit backfilled with arisings.

Stability: Sides Stable

Trial Pit Log

Geo Environmental Group

TrialPit No **IT42** Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489565.39 - 99458.15 Level:	Date 23/10/2019
Location: Hook Lane, Pagham, PO21 3PD		Dimensions (m): 2.00 x 0.90 Depth 1.80	Scale 1:25
Client: Brookbanks / Hallam Land Management			Logged NN

Water Strike	Samples & In Situ Testing: Depth	Type	Results	Depth (m)	Level (m)	Legend	Stratum Description
				0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
				0.30			(Medium dense) orangish brown clayey silty sandy fine to coarse GRAVEL of sub-rounded quartzite and flint. (POSSIBLE RAISED BEACH DEPOSITS)
	0.60	LB		0.70			(Firm to stiff) pinkish brown mottled grey slightly gravelly CLAY with occasional boulder sized lenses of sand and gravel. Gravel is fine sub-angular mudstone nodules. (NATURALLY REWORKED LONDON CLAY FORMATION)
▼	1.50	HVP	120	1.50			Stiff pinkish brown mottled grey slightly gravelly CLAY. Gravel is fine sub-angular mudstone nodules. (LONDON CLAY FORMATION)
	1.50	HVP	120				
	1.50	HVP	120				
				1.80			End of Pit at 1.800m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Remarks: 1. Groundwater encountered at 1.50m as very slow flow. 2. Infiltration test undertaken in trial pit. 3. HVP=Uncorrected Hand Vane Measurement. 4. Upon completion trial pit backfilled with arisings.

Stability: Sides Stable

Trial Pit Log

Geo Environmental Group

TrialPit No **IT43** Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: 489600.47 - 99481.60 Level:	Date 23/10/2019
Location: Hook Lane, Pagham, PO21 3PD		Dimensions (m): 2.00 x 0.90 Depth 2.00	Scale 1:25
Client: Brookbanks / Hallam Land Management			Logged NN

Water Strike	Samples & In Situ Testing: Depth	Type	Results	Depth (m)	Level (m)	Legend	Stratum Description
				0.00			(Soft) dark brown slightly sandy silty CLAY. (TOPSOIL)
				0.30			(Soft to firm) greenish brown and brown sandy gravelly silty CLAY. (POSSIBLE RAISED BEACH DEPOSITS)
				0.50			(Loose to medium dense) yellowish brown silty sandy fine to coarse GRAVEL of sub-rounded flint with occasional boulder-sized lenses of clay. (POSSIBLE RAISED BEACH DEPOSITS)
▼	0.80	LB		0.90			(Soft) pinkish brown sandy clayey SILT with numerous boulder-sized lenses of (very soft) silt and yellowish brown gravelly sand. Gravel is medium sub-rounded flint nodules. (REWORKED LONDON CLAY FORMATION)
				1.80			(Stiff) pinkish brown CLAY. (LONDON CLAY FORMATION)
				2.00			End of Pit at 2.000m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Remarks: 1. Groundwater encountered at 1.20m as slow flow. 2. Infiltration test undertaken in trial pit. 3. Upon completion trial pit backfilled with arisings.

Stability: Sides Stable

Trial Pit Log

Geo Environmental Group

TrialPit No **PCB01** Sheet 1 of 1

Project Name: Hook Lane, Pagham	Project No. GEG-19-623	Co-ords: - Level:	Date 24/10/2019
Location: Hook Lane, Pagham, PO21 3PD		Dimensions (m): 0.10 x 0.10 Depth 0.20	Scale 1:25
Client: Brookbanks / Hallam Land Management			Logged NN

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
	0.10	D		0.00			(Firm) dark brown slightly sandy silty CLAY. (TOPSOIL)
				0.20			End of Pit at 0.200m

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Remarks: 1. No groundwater encountered. 3. Upon completion trial pit backfilled with arisings.

Stability: Sides Stable