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217 Kingston Road, Teddington

Basement Impact Assessment and Flood Risk Assessment

Midco Holdings Limited

Report No. L1338-GEO-R001
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Non-Technical Summary

ByrneLooby (BL) has been appointed by Create Design Limited on behalf of Midco Holdings Ltd (MH), the Client, to provide a Basement Impact Assessment (BIA) and a Flood Risk Assessment (FRA) report to support the planning application for the proposed development at the site of 217 Kingston Road, Teddington, TW11 9JN. The development is within the borough of Richmond Upon Thames and the request for planning permission is made to the Richmond Upon Thames Borough Council.

The proposed development at the site is split into two phases. For Phase 1, the proposal is to construct a new detached building of three storeys with a single storey basement (totalling four storeys) under the full plan area of the building. The development will accommodate seven apartments. The planned dimensions of the proposed basement are approximately 11.00m x 16.00m and will be founded at a depth of 2.60m below ground level (m bgl). A raft foundation is proposed along the site to allow for the construction of the new extended basement. Phase 2 of the development comprises the development of a two storey eco-house with a single storey full plan basement, to be founded at approximately 1.50m bgl.

A review of the history of the site using freely available information indicates that the property comprised open fields until circa 1911 to 1912, after which the footprint of the previous Victorian property (understood to have been demolished by circa May 2018) was identified. The site remained relatively unchanged until the demolition. The area immediately surrounding the site was built up as a predominantly residential area. A review of recent Google Earth historical aerial imagery indicates that area immediately surrounding the site has been relatively unchanged since circa December 2003, and currently comprises predominantly residential dwellings with some light commercial buildings.

A ground investigation was undertaken by Risk Management Limited (RML) in November and December 2016, which comprised the drilling of three dynamic sampler boreholes (BH1 to BH3) to depths of between 7.00m bgl and 9.00m bgl. In-situ testing was carried out during the investigation, and three rounds of ground gas and groundwater monitoring data were undertaken on a weekly basis following the investigation. Two down hole falling head permeability tests were undertaken, which indicated a permeability range within the Kempton Park Gravel Member between 7.58×10^{-5} to 8.10×10^{-6}, indicating good to poor permeability.

A revised conceptual ground model (CSM) has been created for the site, based on a review of freely available published and unpublished geological and hydrogeological information, and the findings of the RML ground investigation. The site is expected to comprise a layer of Made Ground at the ground surface, up to 2.20m in thickness in the area of the previous Victorian's houses basement (though it is understood that the basement box is still in-situ), thinning out across the rest of the site to approximately 0.60m thickness. Beneath the Made Ground, a layer of the Langley Silt Member, with an average thickness of 1.10m was identified, which overlay the Kempton Park Gravel Member which varied significantly in thickness between 3.50m to 7.50m from west to east of the site. The base of the London Clay Formation was not proven during the RML ground investigation.

Groundwater was identified in the RML boreholes at depths between 3.35m bgl and 4.00m bgl, indicating that groundwater is likely to be encountered below the deepest proposed basement level. However, regionally, groundwater levels were identified at shallower depths, so full waterproofing of the basement is still going to be required as part of the proposed development.

A flood risk assessment has been undertaken on the site, the site has been split into three catchment areas (Catchments 1 to 3), with catchment 1 being located across Phase 1, catchment 2 located across the central car parking area of the site, and catchment 3 located across Phase 2. The findings of the post-development hydraulic assessment indicate the area (m^2) of permeable drainage for the proposed development is anticipated to be equal to the pre-demolition permeable drainage area (m^2), thus the proposed development will not negatively impact the surface water drainage potential. Provisional dimensions and depths for soakaway drainage cells have been provided, to be installed within either Catchment 2 or Catchment 3, it is recommended that surface and foul water from the Catchment 1 area is drained into the existing drainage infrastructure below Kingstone Road.

The findings of the basement impact screening and scoping assessment identified the following; for the subterranean characteristics screening, the basements shall be constructed to a maximum depth of approximately 2.60m below ground level anticipated to be approximately ~0.75m to ~1.00m above the groundwater table. The site is underlain by a Principal Aquifer in the Kempton Park Gravel Member, and as such the groundwater flows are expected to be of a high volume. It is expected that with groundwater lower than the proposed deepest basement, subterranean drainage pathways shall not be significantly impacted by the proposed development, particular as the existing basement box is understood to still be present beneath the site.

For the land stability screening, no significant slopes are expected on the site or on the neighbouring properties, nor are significant changes to the site's topography proposed as part of the proposed development. It is understood that the existing basement box is still present beneath the site, during the removal/demolition of this basement box, it is considered that there will be a low risk of ground instability within the underlying Kempton Park Gravel Member. Good practice construction/demolition techniques will limit the likely instability of the removal of the basement box.

For the flood risk and drainage screening, the development shall have an impact on the drainage pathways, as the site is currently an open plot allowing relatively free infiltration of rainwaters. Sustainable drainage systems, including green roof spaces, rainwater harvesting, and permeable paving are proposed to manage this (further outlined in Section 5 of this report). Given that the depth to the underside of the deepest proposed basement is anticipated to be above the groundwater table, it is considered unlikely that the basement will have an impact on the groundwater flow paths. The surface water drainage at the site will be changed by the proposed development, however, the overall drainage area on the site is proposed to be approximately equal to the drainage areas present at the site prior to the demolition of the previous property. Further to this, the construction of a suitable SuDS drainage system will further reduce the risk of surface water ponding or flooding on the site. The site is located within a Flood Risk Zone 2, which will need to be accounted for in the design of the proposed building and basement structures.

A ground movement assessment (GMA) has been undertaken for the proposed basement developments using provisional conservative values based on a serviceability limit state (SLS) assessment. The proposed developments have been modelled using Oasys PDisp and XDisp, soil displacement analysis software. PDisp only allows for soil movements as a result of addition or removal of vertical loads, therefore it does not allow for movements induced by any reduction of lateral ground support during the excavation of the basement, retaining wall deflections or pile installation effects.

Based on the assessments completed, the excavation and construction of the proposed basements shall have a negligible effect on the neighbouring properties. With reference to the Burland Scale, category 0 (the anticipated worst case damage scenario to the neighbouring properties, assuming best practice construction techniques are employed) damage is described as the possibility of hairline cracks forming of less than 0.1mm.

1 Introduction

1.1 Introduction

ByrneLooby (BL) has been appointed by Create Design Limited on behalf of Midco Holdings Ltd (MHL), the Client, to provide a Basement Impact Assessment (BIA) and a Flood Risk Assessment (FRA) report to support the planning application for the proposed development at the site of 217 Kingston Road, Teddington, TW11 9JN. The development is within the borough of Richmond Upon Thames and the request for planning permission is made to the Richmond Upon Thames Borough Council.

1.2 Report Objectives

The objectives of this report are as follows:

1. To provide a summary of the development site, including summarising the site's history, the indicative ground conditions (from freely available published and unpublished sources), hydrology, and hydrogeology;

2. To provide a screening and scoping assessment for the proposed development's basements;

3. To undertake a flood risk assessment in accordance with the requirements of the London Plan Policy SI 13 (Sustainable Drainage, July 2019), National Planning Policy Framework (NPPF, July 2021), the National Planning Practice Guidance (NPPG, June 2021) and the London Borough of Richmond upon Thames Strategic Flood Risk Assessment (SFRA, March 2021). Additionally, this report will provide recommendations for the proposed drainage hierarchy of the proposed development, and;

4. To provide recommendations and conclusions for the site, based on the results of the screening and scoping process. These recommendations will outline the required next steps to support the planning application for the proposed development, including the requirements for a ground investigation to provide detailed information on the existing site conditions, permeability characteristics and to provide the required information for the completion of the Ground Movement Assessment (GMA) report.

1.3 Information Received

Site Plan Drawings:

- 240 2 PL(10) P00 - Planning Application Proposed Site Plan – Rev H
- 240 2 B(10) – Site Location Plan – Rev B

Phase 1 Drawings:

- 240 PL(20) E01 – Proposed Front and Rear Elevation – Rev H
- 195 PL(20) E02 – Proposed Side Elevations – Rev H
- 195 PL(20) P00 - Planning Application Proposed Ground Floor – Rev J
- 195 PL(20) P01 - Planning Application Proposed First Floor – Rev I
- 195 PL(20) P-1 - Planning Application Proposed Lower Ground Floor – Rev I
- 195 PL(20) P02 - Planning Application Proposed Second Floor – Rev I

Phase 2 Drawings:

- 240 2 PL(20) E01 – Proposed Front Elevation – Rev C
- 240 2 PL(20) E02 – Proposed Rear Elevation – Rev C
- 240 2 PL(20) E03 – Proposed Side Elevations – Rev B
- 195 PL(20) P00 - Planning Application Proposed Ground Floor – Rev D
- 195 PL(20) P01 - Planning Application Proposed First Floor – Rev C
- 195 2 PL(20) P-1 - Planning Application Proposed Lower Ground Floor – Rev C
- 240 2 PL(20) S01 - Proposed Section AA – Rev B

Existing Building Drawings:

- 8938-01 to 8938-10 – Survey Drawings

Historical Site Investigation (SI) Report:

- Risk Management Limited (2016). Key Plan and Results of Site Investigation Works at 217 Kingston Road, TW11 9JN.
- Risk Management Limited (2022). Letter of Reliance for Site Investigation Report.

The most recent development drawings are appended to this report as Appendix A, and the Risk Management Limited (henceforth abbreviated as RML) site investigation report and letter of reliance are provided as Appendix B.

It should be noted that the above lists are not exhaustive and represent the documents relevant to the design works undertaken.

1.4 Proposed Development

The whole site is roughly 71.00m x 15.00m. The previous building at the site was a three storey and basement Victorian residential property comprising a detached double fronted house with a converted loft and a basement over half the area of the house, based on drawing 8938-08. The previous building was demolished in between July 2017 and May 2018, based on google earth aerial photography records.

A new development was first proposed in October 2016 and was revised in January 2017. The notable changes to the planning application were a new roof design from an Open Gabel roof to an Intersecting Hip roof on the Phase 1 apartment block building, and a revision to the layout of the proposed car parking area in the central region of the site.

The site is currently an empty plot of land following the demolition of the previous Victorian property, noted to have occurred by circa May 2018. The site has also been levelled with the filling of the northeast section of the site.

The proposed development at the site is split into two phases. For Phase 1, the proposal is to construct a new detached building of three storeys with a single storey basement (totally four storeys) under the full plan area of the building. The development will accommodate seven apartments.

The development will comprise a footprint of approximately 180m^2. The planned dimensions of the proposed basement are approximately 11.00m x 16.00m and will be founded at a depth of 2.6m below ground level (m bgl). The previous property footprint was approximately 145m^2 with an L shaped basement with approximate dimensions of 9.00m x 6.00m, which was founded at a depth of approximately 1.8m bgl. A raft foundation is proposed along the site to allow for the construction of the new extended basement.

Phase 2 of the development at 217 Kingston Road comprises the development of a two storey eco-house with a full plan basement, to be founded at approximately 1.50m bgl. The planned dimensions for the eco house are approximately 14.00m x 11.00m. It is understood that the development will incorporate green roofs, rainwater harvesting methods and areas of permeable paving to support the planning application in line with the London Borough of Richmond upon Thames Strategic Flood Risk Assessment guidance.

The proposed site plan for the development is shown in Figure 1, below.

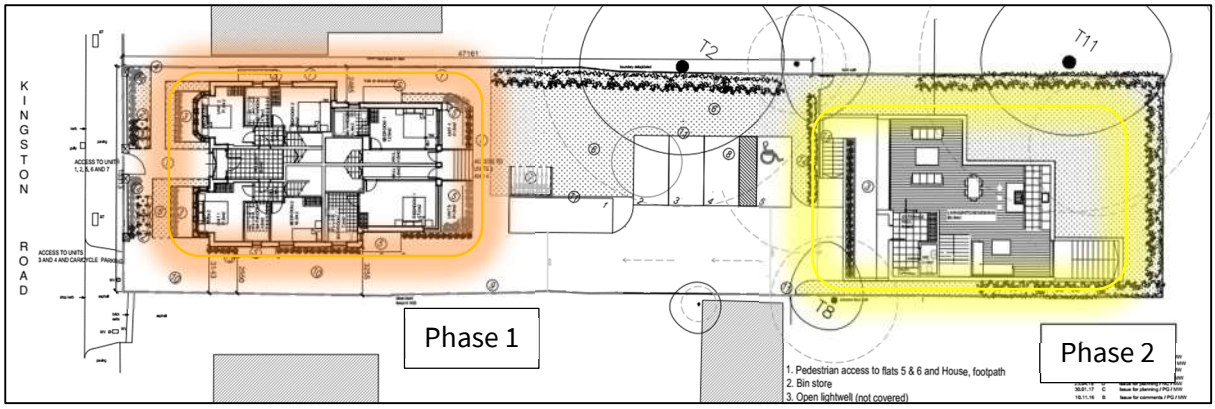


Figure 1 – Proposed Site Plan, drawing reference: 240 2 PL(10) P00

1.5 Planning Context

Planning permission is in progress for the construction of the two proposed developments shown in Figure 1, under the planning application reference 19/3053/FUL. The most recent application was received by Richmond Council on 10/10/2019 based on information sourced from the Planning Detail – London Borough of Richmond upon Thames website, accessed 01/02/2022.

Two previous FRA and Ground Movement Assessment (GMA) reports have been completed by ByrneLooby and submitted during the design conception to support the previous planning application references 18/2033/FUL and 18/2200/FUL. This report shall expand on the previous submissions to provide the screening and scoping aspects of the Basement Impact Assessment, and to include an updated FRA in line with the March 2021 updates to the London Borough of Richmond upon Thames Strategic Flood Risk Assessment.

It is understood that the following feedback has been provided from the Local Authority based on the previous planning application. In relation to concerns over flooding and drainage, the following concerns were raised:

Drainage hierarchy

- *Infiltration features are proposed where ground conditions do not appear to be suitable (the site is susceptible to groundwater flooding below ground and a basement forms part of the site) but no evidence has been provided to show that a suitable infiltration rate is available. A groundwater investigation report should be provided and infiltration testing to establish feasibility of discharging surface water via infiltration to the ground should be undertaken.*

Runoff rate

- *The application does not conform to Defra's Non-Statutory Technical Standards for Sustainable Drainage. We cannot assess the application due to missing runoff rate information. You should submit the greenfield, existing and proposed runoff rates, which should be supported by drainage calculations that include the total site area. It must be demonstrated that the site will not flood as a result of the 1 in 30-year rainfall event, that there will be no flooding of buildings as a result of events up to and including the 1 in 100-*

year rainfall event, and on-site flow as a result of the 1 in 100 year event with a climate change consideration must be suitably managed.

- *The application also lacks a basement screening assessment. The proposal includes a basement, and the site is located in an area with a greater than 75% susceptibility to groundwater flooding (part of the site is located in an area with between 50 and 75% susceptibility to groundwater flooding).*

This report will look to address the above concerns, other concerns were raised by the planning authority, but they are considered to be outside the scope of this report. This report has been written with reference to London Plan, Policy SI 13 and Non-Statutory Technical Standards for SuDS S7-S9. A whole life assessment of the proposed structure is to be considered.

2 Development Location and Features

2.1 Development Location

The proposed development is located at 217 Kingston Road, Teddington, TW11 9JN. The approximate National Grid coordinates for the centre of the site are 517010 east and 170517 north. A site layout plan is presented as Figure 2.

Figure 2 – Aerial photograph showing the site (Source: Google Maps, accessed 28/01/2022)

The topography of the site has been levelled out during demolition of the previous property to approximately 7.00m above ordinance datum (m AOD). Prior to demolition, the previous property had a gradual slope of approximately 7.20m AOD to 7.49m AOD from southwest to northeast, with a slight dip in the approximate centre of the property, behind the former house (to a low level of 6.76m AOD). The River Thames is located approximately 1200m to the east of the site at its closest point.

The buried services are anticipated to be standard residential and commercial utilities, and that deep infrastructure (e.g. deep buried sewers) are not anticipated.

2.2 Site History

The site was originally an open field adjacent to the Broomhill house in 1864-1870 as shown on the map 'Middlesex Sheet XXV' from the National Library of Scotland Website (accessed 28/01/2022). The plot of land and the previous Victorian property first appeared in 1911-1912 on the map 'Surrey Sheet VI.SE' from the National Library of Scotland Website.

The immediate area surrounding the site was developed as a predominantly residential area throughout the 1900's with addition residential dwellings constructed directly around the site. A review of recent Google Earth historical aerial imagery indicates that area immediately surrounding the site has been relatively unchanged since circa December 2003, and currently comprises predominantly residential dwellings to the north, east and south of the site, and a mixture of residential dwellings and light commercial buildings to the west of the site.

The previous building was demolished in between July 2017 and May 2018, based on google earth aerial photography records. It is understood from the Client's representative that the previous basement 'box' (outer walls) was retained post-demolition and is still present beneath the site.

2.3 Geological Setting

2.3.1 Published Geology

The relevant extract from the British Geological Survey (BGS) 1:50,000 scale map (Sheet 270, Solid and Drift Edition, South London, 1998) is provided in Figure 3 below.

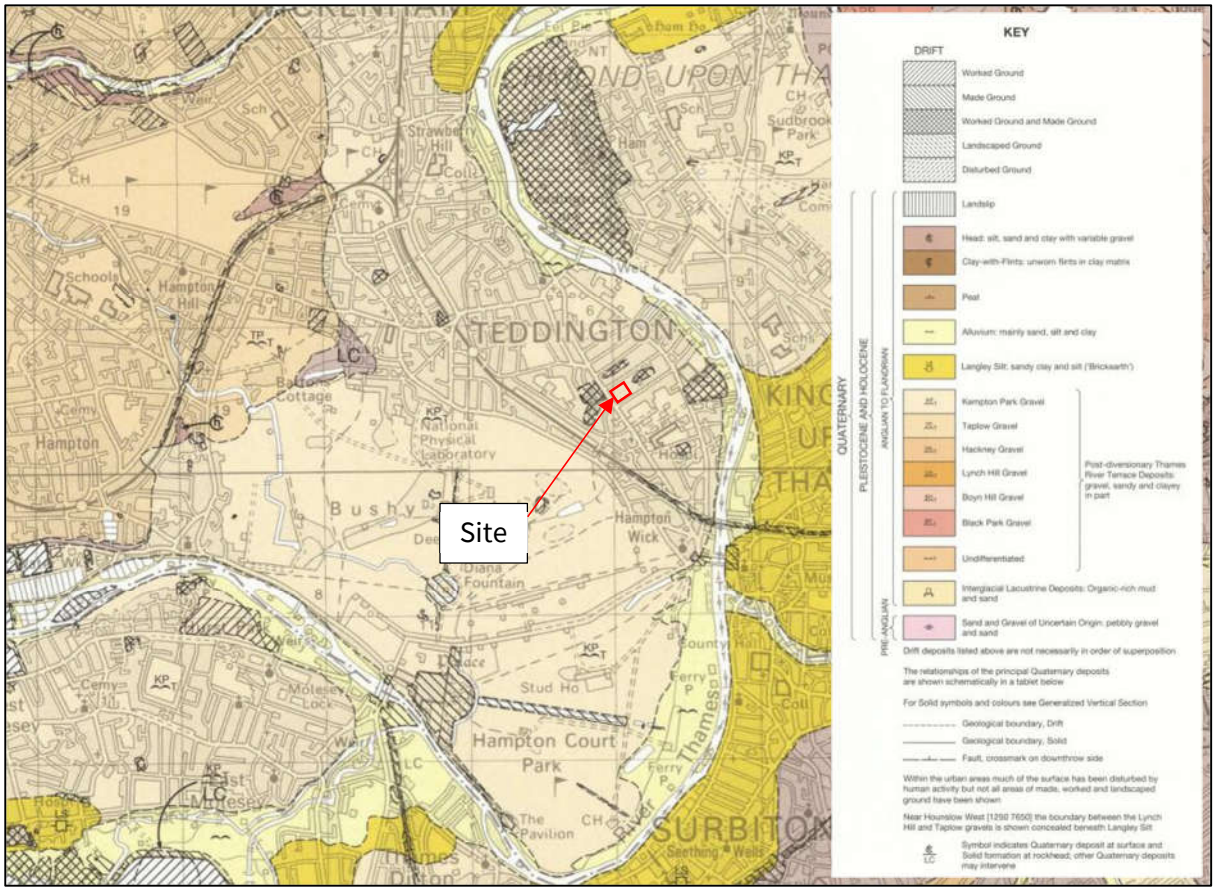


Figure 3 – BGS 1:50,000 scale map (Sheet 270, Solid and Drift Edition, South London) extract

A review of the BGS geological map sheet indicates that the site is underlain by superficial deposits of the Kempton Park Gravel Member, underlain by bedrock of the London Clay Formation, with an approximate thickness of 50m in the region. At depth, the Lambeth Group Formation, Thanet Sand Formation and Upper Chalk are anticipated.

The BGS online Geoindex indicates that Artificial Ground deposits are present within the immediate vicinity of the site. Worked Ground and Made Ground is present in multiple locations nearby to the site within a 500m radius of the site, as shown in Figure 3.

The BGS online geology Lexicon and BGS onshore Geoindex provides the following lithological descriptions for the anticipated ground conditions at the site:

- The superficial geology at the site consists of the Kempton Park Gravel Member - Sand and Gravel. The superficial Deposits formed up to 2 million years ago in the Quaternary Period.

The local environment was previously dominated by rivers, therefore the geological setting for the Kempton Park Gravel Member is rivers. The deposits are sedimentary and fluvial in origin. They are detrital, ranging from fine to coarse grained and form beds and lenses of deposits reflecting the channels, floodplains and levees of a river.

- The bedrock geology at the site consists of the London Clay Formation - Clay and Silt. The Bedrock is sedimentary and formed approximately 48 to 56 million years ago in the Palaeogene Period. The local environment was previously dominated by deep seas, therefore the geological setting for the London Clay is deep seas. The clays are highly consolidated and formed from marine sediments. They are detrital and comprise fine to coarse grained slurries of debris from the continental shelf flowing into a deep-sea environment, forming distinctively graded beds.

2.3.2 Unpublished Geology

A review of the BGS onshore Geoindex indicates that there are four historical borehole records within an approximate 600m radius of the site. A summary of the boreholes records is included in Table 1, below, and the borehole recorded as provided in Appendix C.

Table 1 – Unpublished borehole records summary

BGS Borehole Ref and Coordinates	Approximate distance from site* (m)	Maximum Depth (m bgl)	Log Descriptions (m bgl)	Groundwater Depth (m bgl)
TQ17SE22 (E517300, N170800)	BROOM ROAD TEDDINGTON. Approximately 500m northeast of the site	3.65	0.00 to 1.00 – Soft clayey sand 1.00 to 3.65 – Sand and Gravel	None.
TQ17SE115 (E516500, N170700)	CROMWELL ROAD TEDDINGTON. Approximately 600m northwest of the site	42.70	0.00 to 0.80 – Made Ground 0.80 to 3.00 – Sandy clay and stones 3.00 to 6.00 – Gravel and brown clay 6.00 to 42.70 – Brown/blue clay and claystone	Not recorded.
TQ17SE113 (E517200, N170200)	HAMPTON WICK. Approximately 450m south of the site	6.10	0.00 to 0.50 – Made Ground 0.50 to 1.60 – Loamy sand 1.60 to 6.10 – Ballast/Gravel	2.45
TQ17SE26 (E517650, N170500)	BROOM ROAD TEDDINGTON. Approximately 500m east from the site	7.90	0.00 to 0.90 – Made Ground 0.90 to 6.10 – Gravel and sand 6.10 to 7.90 – Stiff blue fissured clay	3.10

In accordance with Drawing 8398 01, the ground level around the proposed development varies between 6.80m AOD and 7.20m AOD, however, it is understood that during demolition of the previous residential dwelling, the site was levelled off. Therefore, a ground level of 7.20m AOD has been adopted for the site. Based on the reviewed historical borehole logs, groundwater was encountered at depths ranging from 2.45m bgl to 3.10m bgl, within the Kempton Park Gravel Member.

A preliminary ground model has been adopted by referring to the findings of the published and unpublished geological records, in particular, the four boreholes reviewed above. Further details of the preliminary ground model are provided in Section 4 of this report.

2.4 Hydrogeological Setting

2.4.1 Groundwater in the London Basin

There are two main water bearing aquifers in the London Basin. These are separated from each other by the relatively impermeable London Clay. The aquifers are referred to as:

- Upper Aquifer – this comprises the Principal Aquifer within the Kempton Park Gravel Member, which overlies the London Clay Formation.
- Lower Aquifer – this comprises the Principal Aquifer within the Thanet Sand Formation and Upper Chalk (which underlie the Lambeth Group Formation in sequence).

2.4.2 Aquifer Designation by the Environment Agency

The Environment Agency (EA) protect groundwater by identifying different types of aquifers. The EA's aquifer designation data is based on geological mapping provided by the British Geological Survey.

The areas of overlying Kempton Park Gravel Member are designated as a "Principal" aquifer meaning that *"these are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale".*

Underlying this, is the London Clay Formation, which is classified as 'Unproductive Strata', meaning that "*these rocks have negligible significance for water supply or baseflow to rivers, lakes and wetlands. They consist of bedrock or superficial deposits with low permeability that naturally offer protection to any aquifers that may be present beneath*". This stratum will act as an aquiclude (An impermeable body of rock or stratum of sediment), which severely limits vertical migration of groundwater.

The Lower Aquifer, located beneath the London Clay Formation and Lambeth Group Formation comprises the Thanet Sand Formation and Upper Chalk is also classified as "Principal" Aquifer.

2.4.3 Upper Aquifer

The Upper Aquifer is a Principal Aquifer, acting as the free standing groundwater table, which naturally flows towards the River Thames due to the regional topography sloping slightly downwards to the east. A map of the Upper Aquifer's regional coverage is presented in Figure 4, below.

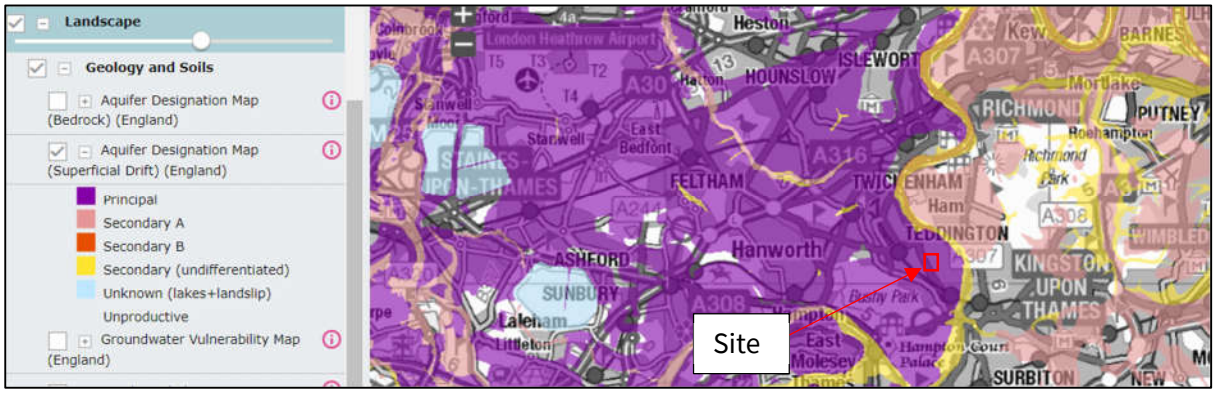


Figure 4 – Superficial Aquifer Designation (Magic Maps)

For the proposed basements, the Upper Aquifer is the most relevant as this is the groundwater table that could be encountered when undertaking the excavations for the proposed basements, and against which the basements should be designed structurally and waterproofed.

Two of the historical BGS boreholes records encountered groundwater at 2.45m bgl to 3.1m bgl although it should be noted that free standing groundwater levels are susceptible of change due to seasonal variations, rain periods or during flood events.

The groundwater levels within the historical BGS boreholes indicate that ground water level in the upper aquifer is typically slightly above the River Thames level and is expected to deepen slightly closer to the River Thames. The nearest catchment (at the River Thames) altitude is 4.0m AOD.

2.4.4 Lower Aquifer

The Lower Aquifer is the larger of the two aquifer systems in London and has been utilised for the purpose of water supply for industry and drinking water since the late 18th century and is a protected resource.

The Lower Aquifer is confined beneath the unproductive strata of the London Clay Formation and Lambeth Group Formation, well below the level of proposed basement, and presented in Figure 5.

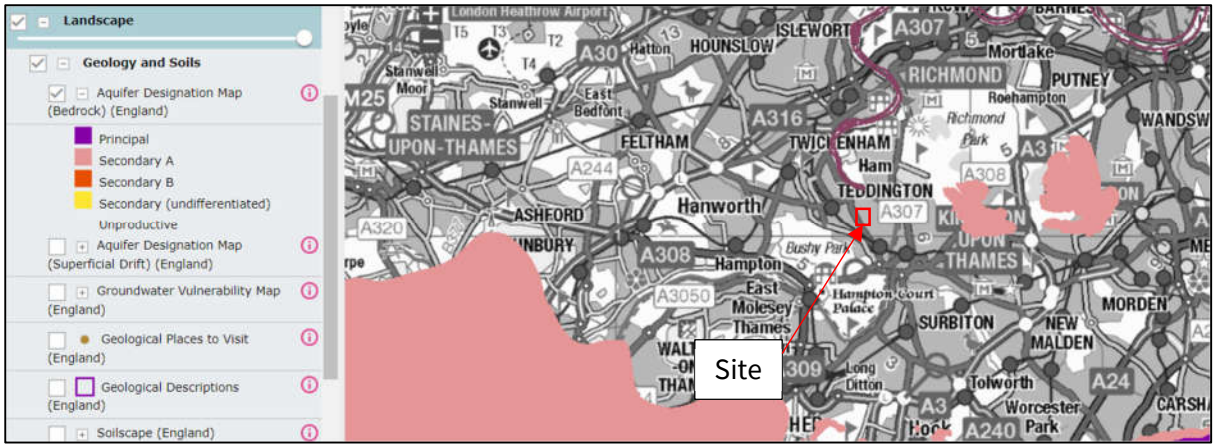


Figure 5 – Unproductive Bedrock Aquifer (Magic Maps)

Since the 1990s there has been concern that changes in the level of the Lower Aquifer could impact upon deep basements and subterranean infrastructure, unless mitigating measures were undertaken. Industrial abstraction from the Lower Aquifer had been increasing until around late 1960s, causing regional groundwater levels to drop significantly below the natural baseline level that characterised the Lower Aquifer prior to significant abstraction for industrial purposes. In the post-industrial era, water levels in the aquifer had started to increase towards pre-industrial levels, so much so that it became apparent that if the water level continued to rise, the water pressures in the sands and clays above the Chalk would increase, causing ground movements in the clays. These pressure changes and associated ground movement could damage some large buildings and underground infrastructure. However, given that the anticipated thickness of the London Clay Formation regionally is around 50m, it is considered that the impact of these deep groundwater level changes are highly unlikely to impact the proposed basements at the site.

A program of aquifer dewatering was undertaken in the London area to control the groundwater level. The ongoing programme of dewatering has now largely stabilised groundwater levels protecting deep foundations, deep basements and subterranean infrastructure from adverse impacts.

2.4.5 Groundwater Extractions

A licensed “Medium Size” groundwater abstraction is located within half a mile North of the site. The license is for irrigation use.

The site is not near any “Groundwater Source Protection Zones” in accordance with the EA Groundwater Source Protection Zones map. The site is located within a Medium-Low groundwater vulnerability area, as presented in Figure 6.

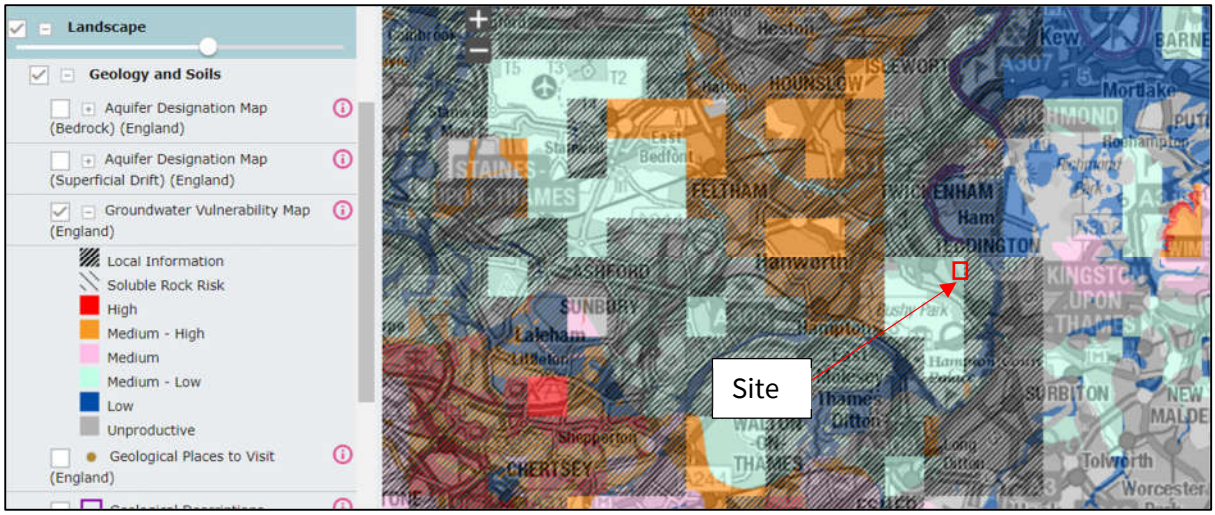


Figure 6 – Medium-Low Groundwater Vulnerability (Magic Maps)

2.5 Hydrological Setting

The River Thames is the largest watercourse in the vicinity of the site. It is located approximately 1,200m to the east of the site (at its closest point), flows in a north to north-easterly direction (towards central London). Additionally, the ponds located at Hampton Wick, some 780m south east of the site (at the closest point) are considered to be 'upstream' of the site and appear to flow in an easterly to north easterly direction.

The approximate level of the site is 7.20m AOD, which is some 1.00m to 2.00m above the level of the River Thames, depending on water level (at approximately 5.50m AOD), and approximately 1m below the level of the ponds at Hampton Wick. Based on the local topography, it is anticipated that the general regional groundwater flow direction will be in an easterly to north easterly direction, towards the River Thames.

The development is located less than a mile upstream from the Teddington Weir, which separates the fluvial Thames from the tidal Thames. At the nearest catchment point (No 39001 - Thames at Kingston), located 1 mile upstream of the Teddington Weir, the River Thames comprises a catchment area of almost 10,000km^2 and carries a mean flow of 66m^3/s. The catchment altitude is 4.00m AOD. The location of the Teddington Weir in relation to the site is presented as Figure 7.

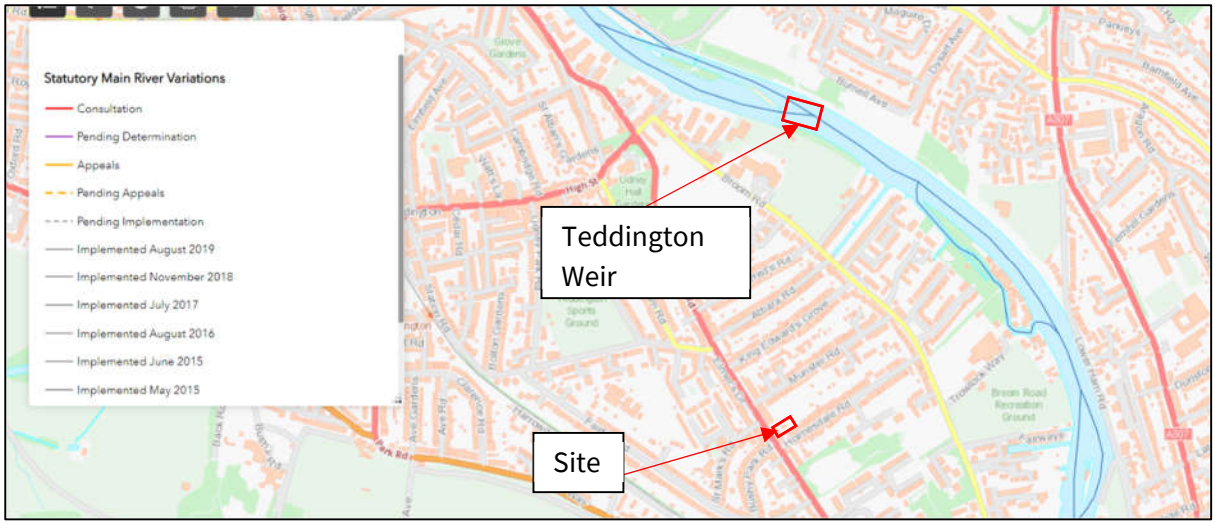


Figure 7 - Teddington Weir Location Map (Environmental Agency)

No tributaries discharge into the River Thames within 1 km of the site boundary.

The catchment is situated in one of the driest regions in the UK and receives an average 690mm of rainfall per annum, much lower than the national average of 897mm. The site is within a developed area, therefore water run-off largely drains through the local sewer and drainage network.

Based on the maps published by the Environmental Agency (presented as Figure 8), the entire site is shown to lie within 'medium probability' Flood Zone 2 which represents an annual probability of between a 1% - 0.1% (1/100 to 1/1000) chance of fluvial flooding in any one-year period. The gradient at the site is approximately 0.5%.

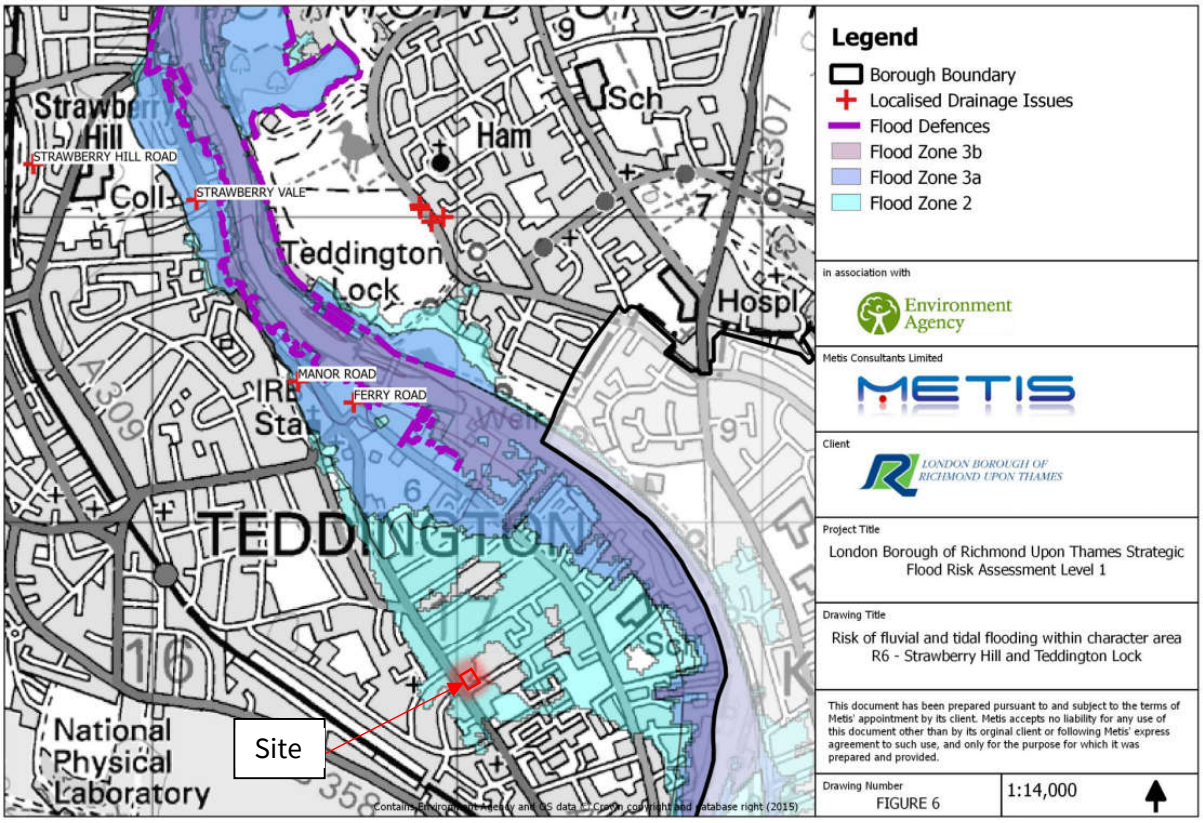


Figure 8 - Flood Zone Map (SFRA)

2.6 Other Information

The site has been identified as being located within a low buried unexploded ordnance (UXO) risk area through Zetica UXO maps.

3 Review of Historical Site Investigation Data

3.1 Introduction

A ground investigation was undertaken by Risk Management Limited between 21st November 2016 and 23rd November 2016, with three follow up monitoring rounds undertaken between 28th November and 12th December 2016. A letter of reliance on the ground investigation report was supplied by Risk Management Limited on 22nd February 2022.

The RML report comprised a factual and interpretative Geotechnical Interpretative Report (GIR) and did not comprise a Phase I desk study. The findings of the RML report are further outlined in the following section.

A copy of the RML report is appended to this report as Appendix B.

3.2 Ground Investigation Scope

The RML ground investigation comprise the drilling of three dynamic sampler boreholes (BH1 to BH3) to depths of 7.00m bgl, 8.00m bgl and 9.00m bgl for boreholes BH1, BH2 and BH3 respectively. In-situ testing, comprising Standard Penetration Testing (SPTs) were undertaken within the Kempton Park Gravel Member in each of the boreholes, and the test depths ranged between 2.0m bgl and 5.0m bgl. Undisturbed (U) sampling was undertaken at depth within the London Clay Formation.

Ground gas and groundwater monitoring standpipes were installed within two of the borehole locations (BH1 and BH3, located at opposing ends of the site) to depths of 4.60m bgl and 5.00m bgl, within the Kempton Park Gravel Member.

Three rounds of ground gas and groundwater monitoring were undertaken over a three week period. Additionally, downhole permeability (falling head) testing was undertaken during one of the monitoring visits (the date of the testing was not provided on the report) to assess the permeability of the Kempton Park Gravel Member stratum. One falling head test was undertaken in each of the two monitoring installations at depths of 3.35m bgl (in BH1) and 3.50m bgl (in BH3).

Geotechnical laboratory testing was undertaken on selected samples gathered during the ground investigation, the results of which will be further summarised in the following sections.

3.3 Ground Conditions

The ground conditions encountered during the RML ground investigation are summarised in Table 2, below. Ground levels were not provided on the borehole logs, so approximate levels based off the nearest topographical point from the topographical site survey drawing no. 8938-01 from 16th September 2016 have been adopted.

Table 2 – Summary of RML Report Ground Conditions

Stratum Description	Top of Strata Level (m bgl) [mOD]	Thickness (m)
Topsoil with roots. [TOPSOIL] *(encountered in BH1 and BH3 only)*	0.00 [7.23 to 7.30]	0.05 to 0.20
Dark brown sand with brick fragments and roots. Or, Brown silty sandy clay with brick fragments. [MADE GROUND]	0.00 to 0.20 [7.03 to 7.25]	0.35 to 0.90
Firm orange brown to light brown frequently silty sandy CLAY with occasional roots. [LANGLEY SILT MEMBER] *(described as 'Superficial Clay' on the RML logs)*	0.40 to 1.10 [6.13 to 6.90]	0.90 to 1.40
Very loose to medium dense brown and orange brown silty SAND and GRAVEL. [KEMPTON PARK GRAVEL FORMATION]	1.30 to 2.20 [5.03 to 6.00]	3.50 to 7.50
Stiff to very stiff brown becoming grey with depth silty CLAY. [LONDON CLAY FORMATION]	5.70 to 8.80 [-1.50 to 1.53]	Proven thickness: 0.20 to 1.30 Base not proven.

Generally, the ground conditions encountered during the RML ground investigation are consistent with the published and unpublished geology for the area. However, a thin layer of the Langley Silt Member (LSM, occasionally described as 'Brickearth') was encountered in each of the three boreholes, at depths of between 0.40m bgl to 1.10m bgl which was not encountered on historical BGS borehole logs.

The depths to the Kempton Park Gravel Member and London Clay Formations vary significantly from the south west of the site (where BH1 was drilled) to the north east of the site (where BH3 was drilled). The Kempton Park Gravel Member layer was identified to be thinner in the area beneath the proposed deeper Phase 1 basement, with an approximate thickness of 3.50m.

3.4 Summary of Geotechnical Laboratory Testing

A summary of the geotechnical laboratory testing undertaken during the RML ground investigation is summarised in Table 3, below.

Table 3 – Summary of Geotechnical Laboratory Testing

SPT 'N' Data						
Strata					**Range of SPT 'N' values**	
Kempton Park Gravel Member (Granular)*					1 to 15	
Particle Size Distribution (%)						
Strata	**Very coarse (>63mm)**	**Gravel**	**Sand**	**Silts & Clays (<0.063mm)**		
Kempton Park Gravel Member	0	2	97	1		
Atterberg Limits						
Strata	**Moisture Content (%)**	**Liquid Limit (%)**	**Plastic Limit (%)**	**Plasticity Index (%)**	**% material <425µm**	**Modified Plasticity Index [I'p] (%)**
Langley Silt Member	5	23	11	12	95	11.4
London Clay Formation	23 to 25	59	24	35	100	35
Shear Strength Tests – cu (kPa)						
Strata					**Undrained Triaxial**	
London Clay Formation					170 to 223	
Sulphate Content						
Strata	**pH**	**Total Sulphate as SO4 (mg/kg)**	**Water Soluble SO4 16hr extraction (2:1 Leachate Equivalent) (g/l)**	**Total Sulphur (mg/kg)**		
Langley Silt Member	4.8 to 7.6	<20 to 200	N.R.	N.R.		

Note: N.R. – not reported. * The SPT undertaken at 2.0m bgl in BH1 was undertaken between the Langley Silt Member and the Kempton Park Gravel Member. Given that the majority of the test was undertaken through the Kempton Park Gravel Member, the SPT results have assessed as being within the Kempton Park Gravel Member.

3.5 Groundwater

Groundwater strikes were encountered in each of the three boreholes during the ground investigation. Additionally, three groundwater monitoring visits were undertaken on the two installed boreholes (BH1 and BH3). A summary of the groundwater findings from the RML ground investigation are summarised in Table 4, below.

Table 4 – Summary of RML Groundwater findings

Location	Well Response Stratum	Well Response Zone	During ground investigation 21-23/11/2016	Monitoring visit 1 28/12/2016	Monitoring visit 2 06/12/2016	Monitoring visit 3 12/12/2016
		(m bgl) [m AOD]	(m bgl) [m AOD]	(m bgl) [m AOD]	(m bgl) [m AOD]	(m bgl) [m AOD]
BH1	KPGR	1.00 to 4.60 [2.63 to 6.23]	4.00 [3.23]	3.90 [3.33]	3.50 [3.73]	3.35 [3.88]
BH2			3.50 [3.65]			
BH3	KPGR	1.00 to 5.00 [2.30 to 6.30]	3.60 [3.70]	3.60 [3.70]	3.60 [3.70]	3.50 [3.60]

Based on the findings of the RML ground investigation and monitoring regime, a design groundwater level of 3.60m AOD has been assumed for the site.

3.6 Permeability Testing

Two permeability tests were undertaken during the RML ground gas and groundwater monitoring periods. One falling head test was undertaken at a depth of 3.35m bgl [3.88m AOD] in BH1 and one test was undertaken at a depth of 3.50m bgl [3.80m AOD] in BH3, both within the Kempton Park Gravel Member. The results of the falling head tests are summarised in Table 5, below.

Table 5 – Summary of Falling Head Test Results

Location	Permeability Result [*k*] (*m/sec*)
BH1	$8.10*10^{-06}$
BH3	$7.5*10E^{-05}$

The above permeability results should be used for detailed drainage design within the Kempton Park Gravel Member stratum only.

3.7 Ground Gas Monitoring

Three rounds of ground gas monitoring were carried out at atmospheric pressures ranging between 997mb (low pressure) and 1020mb (high pressure). A summary of the RML ground gas monitoring is summarised in Table 6, below.

Table 6 – Summary of RML Ground Gas Monitoring

Borehole	Date	Pressure (mb)	Steady Flow Rate (l/hr)	O_2 (% vol in air)	CO_2 (% vol in air)	Maximum CH_4 (% vol in air)
BH1	28/11/2016	1001	<0.1	20.0	<0.1	<0.1
	06/12/2016	1020	<0.1	18.2	1.8	<0.1
	12/12/2016	997	<0.1	17.7	2.3	<0.1
BH3	28/11/2016	1001	<0.1	19.9	0.1	<0.1
	06/12/2016	1020	<0.1	19.4	0.6	<0.1
	12/12/2016	998	<0.1	19.1	0.9	<0.1

It is noted that the full ground gas monitoring results were not presented in the RML report, and there is no reference to the ground gas monitoring methodology that was undertaken. Therefore, it is considered that the results presented in Table 6 should be used with caution and may not be suitable for ground gas protection measures design.

4 Conceptual Ground Model

The conceptual ground model assumes a level site with a ground level of 7.20m AOD. The ground is modelled as layers of homogeneous soil with presumed granular Made Ground at the surface, underlain by superficial deposits comprising the (cohesive) Langley Silt Member and (granular) Kempton Park Gravel Member, with a bedrock of the (cohesive) London Clay Formation. Based on the findings of the RML ground investigation, a revised conceptual model is presented as Table 7, below.

Table 7 – Revised Conceptual Ground Model

Stratum Description	Top of Strata Level (m AOD)	Thickness (m)
Made Ground (MG) (Granular)	7.20	2.20 – in the area of the previous basement, 0.60 – across the remainder of the site
Langley Silt Member (LSM) (Cohesive)	6.60 (Phase 2 only)	1.10 (Not present directly beneath the previous building)
Kempton Park Gravel Formation (KPGR) (Granular)	5.00 – in the area of the previous basement, 5.50 – across the remainder of the site	3.50 – Beneath the Phase 1 basement 7.50 – beneath the Phase 2 basement
London Clay Formation (LCF) (Cohesive)	1.50 – Beneath the Phase 1 basement -1.50 – Beneath the Phase 2 basement	To base of the model.

Groundwater was encountered between 3.35mbgl [3.88m AOD] and 4.00mbgl [3.23m AOD] within the boreholes during the RML ground investigation and monitoring period. For the conceptual ground model, the design groundwater level is taken as 3.60m AOD. The above depth ranges should be considered as being relatively representative for seasonal fluctuations in the groundwater level at the site.

4.1.1 Made Ground

A 0.6m to 2.20m thick layer of Made Ground has been adopted across the site, with the increased thickness of Made Ground located beneath the area of the demolished Victorian house, reducing to 0.6m thickness for the rest of the site for the purpose of the ground movement assessment. No geotechnical testing was undertaken within the Made Ground during the RML ground investigation. Therefore, the Made Ground has been assumed to be drained with a conservative effective stiffness of E' = 10 MPa.

4.1.2 Langley Silt Member

The Langley Silt Member layer has adopted a thickness of 1.10m. It was mainly described as a firm light brown to orange brown silty sandy CLAY.

One Atterberg Limits classification test were undertaken on a sample of the Langley Silt Member, which indicated that the material tested would be classified as material of a 'very low' plasticity with a 'low' volume change potential. No further geotechnical testing was undertaken within the Langley Silt Member during the RML ground investigation.

4.1.3 Kempton Park Gravel Member

The Kempton Park Gravel Member layer comprised a variable thickness of between 3.50m to 7.50m. It was mainly described as a medium to coarse SAND with fine to medium flint gravel. The Kempton Park Gravel Member was identified to thicken significantly towards the east of the site, with a recorded thickness of 3.50m in BH1 (to the west) and a recorded thickness of 7.50m in BH3 (to the west).

The vertical stiffness of the Kempton Park Gravel Member is based on the ratio for normally consolidated granular soils E' = 1 x "N", where "N" is the SPT "N" value. Based on the RML boreholes, an average SPT "N" value of 13 has been adopted at the surface of the Kempton Park Gravel Member, which was identified to decrease to an average SPT "N" value of 2 at depths below 4.0m bgl.

One Particle Size Distribution (PSD) test was undertaken within the Kempton Park Gravel Member in BH1 at a depth of 3.50m bgl [3.73m AOD]. The results of the PSD testing indicated that the material comprised a poorly graded silty SAND with a very low gravel content (approximately 2%). No further geotechnical testing was undertaken within the Kempton Park Gravel Member during the RML ground investigation.

4.1.4 London Clay Formation

The London Clay Formation has adopted two surface levels of 1.50m AOD and -1.50m AOD for the Phase 1 and Phase 2 basements respectively. The depths to the London Clay Formation have varied significantly from the west of the site eastwards, based on the high variation in the overlying Kempton Park Gravel Member.

The London Clay Formation was described as stiff to very stiff brown to grey silty CLAY. The base of the London Clay Formation was not identified in the RML ground investigation boreholes and based on the findings of the local BGS historical borehole TQ17SE115, the thickness of the London Clay Formation is expected to be greater than 30m, which corresponds with the published geology for the region.

No SPT results were recorded within the London Clay Formation during the RML ground investigation, however, four undrained triaxial tests were undertaken at depths ranging between 6.50m bgl [0.73m AOD] and 9.00m bgl [-1.70m AOD]. The results ranged between 170kPa in BH1 at 6.50m bgl and 223kPa in BH3 at 9.00m bgl, each of the results increased in stiffness with depth.

One Atterberg Limits classification test were undertaken on a sample of the London Clay Formation, which indicated that the material tested would be classified as material of a 'medium' plasticity with a 'medium volume change potential. No further geotechnical testing was undertaken within the London Clay Formation during the RML ground investigation.

The work undertaken by Burland et al., (2001) entitled 'Building response to tunnelling, case studies from the construction of the Jubilee Line Extension' suggests a factor of E_u/C_u of 600 to be considered for obtaining the stiffness of London Clay.

For the drained stiffness values, the following relationship has been adopted: E' = 0.75Eu.

4.1.5 Geotechnical Design Parameters

The Made Ground and Kempton Gravel Formation are modelled as granular materials in drained conditions. The Langley Silty Member and London Clay Formation are modelled with undrained parameters.

Based on the revised conceptual ground model that has been adopted, the characteristic parameters used in the ground movement assessment are presented in Table 8, below.

Table 8 – Summary of Geotechnical Design Parameters

Strata	Design Level (m AOD)	Unit Weight (kN/m³)	Undrained Cohesion (kPa) [Cu]	Friction Angle Φ' (°)	Undrained Modulus (MPa) [Eu]	Drained Modulus (MPa) [E']
Made Ground	7.2	18	- [-]	28[a]	-	10
Langley Silt Member	6.6 (Phase 2 only)	18	20 [0]	18[b]	12[c]	9[d]
Kempton Park Gravel Member	5.5 / 5.0 Phase 1 / Phase 2	19	- [-]	31[b]	-	50
London Clay Formation	1.50 / -1.50 Phase 1 / Phase 2	20	170 +10z[e] [5]	22[b]	102.4[c] +6z[e]	76.5[d]+4.5z[e]

a. Peck, R.B., Hanson, W.E, and Thornburn, T.H., Foundation engineering, 2nd Edn, John Wiley, New York, 1967, p.310.
b. British Standards Institution (2015). Code of practice for Earth retaining structures. BS 8002:2015.
c. Eu – 600Cu. Based on Burland, Standing J.R., and Jardine, F.M. (eds) (2001). Building response to tunnelling, case studies from the construction of the Jubilee Line Extension, London, CIRIA Special Publication 200.
d. E' = 0.75Eu. Based on Burland, Standing J.R., and Jardine, F.M. (eds) (2001). Building response to tunnelling, case studies from the construction of the Jubilee Line Extension, London, CIRIA Special Publication 200.
e. z = depth below top of stratum.

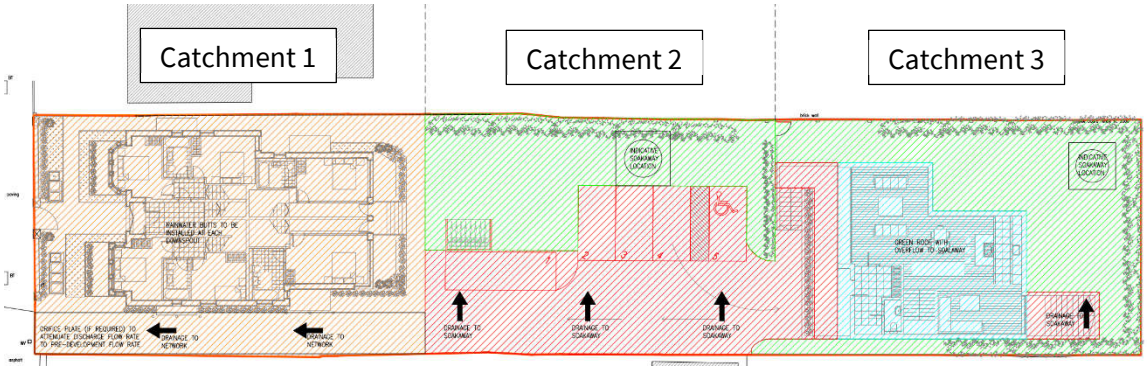
5 Flood Risk Assessment

5.1 Proposed Drainage Hierarchy

A proposed drainage strategy has been prepared to comply with the London Plan, Policy SI 13, Sustainable Drainage in terms of following the established drainage hierarchy and maintaining discharge rates to comply with the pre-development run-off rates.

This strategy separates the site into three separate catchments that each promote different sustainable drainage philosophies. A plan outlying the catchment areas is presented as Figure 9, below, and further details of the catchment plans are presented in Appendix D.

Figure 9 – Catchment Zone Plan



5.1.1 Catchment 1 – Front Portion of Site (Phase 1)

Catchment 1 incorporates the main Phase 1 building and is located that the front (western) portion of the site. To provide sustainable drainage for this catchment, the following drainage philosophies will be implemented:

- Rainwater used as a resource, by including water butts at the roof drainage down spouts of the main building. Overflows will be provided to below ground drainage systems to manage run-off when water butts are full;
- Controlled rainwater discharge to a surface water/combined sewer in Kingston Road. Flows will be controlled using an orifice plate to restrict discharge rates to be equivalent to the pre-development discharge rates from the site.

5.1.2 Catchment 2 – Middle Portion of Site (car parking area)

Catchment 2 incorporates the car parking and gardens in the central portion of the site. To provide sustainable drainage for this catchment, the following drainage philosophy will be implemented:

- Rainwater infiltration to ground at or close to source, by directing run-off from the car parking area to the grassed area, for infiltration to ground by soakaway;

Site investigation works were completed by RML in November 2016, with a corresponding Site Investigation Report in December 2016. This report confirms that:

"The falling head tests gave the following permeability (k) values:

BH1 (SA1) 3.35m depth $8.10*10^{-6}$ m/sec

BH3 (SA2) 3.50m depth $7.58*10^{-5}$ m/sec

These results reflect 'slow' to 'good' drainage characteristics and suggest that conventional soakaways are likely to be successful at this site within the upper more granular deposits."

The site investigation report also confirmed that groundwater was encountered at a depth of 3.35m bgl to 4.0m bgl. The proposed soakaway will be located above these levels to ensure infiltration to groundwater can be achieved.

BH3 is located within Catchment 2, confirming 'good' drainage characteristics with permeability (k) value of $7.58*10^{-5}$ m/sec at this location, and justifying the approach.

5.1.3 Catchment 3 – Rear Portion of Site (Phase 2)

Catchment 3 incorporates the Phase 2 dwelling and gardens at the rear (eastern) portion of the site. To provide sustainable drainage for this catchment, the following drainage philosophies will be implemented:

- Rainwater attenuation in green infrastructure features for gradual release, by utilising a green roof on the dwelling;
- Rainwater used as a resource, by including overflows from the green roof that discharge to water butts. Overflows will be provided to below ground drainage systems to manage run-off when water butts are full;
- Rainwater infiltration to ground at or close to source, by directing overflow from the water butts for infiltration to ground by soakaway.

BH3 is the closest permeability test to Catchment 3, confirming 'good' drainage characteristics with permeability (k) value of $7.58*10^{-5}$ m/sec at this location, and justifying the approach.

5.2 Run-off Rates and Hydraulic Assessment

The catchment areas for the pre-development and post-development have been assessed to identify the areas of permeable and impermeable surfacing that contribute to drainage discharges from the site.

The catchment areas assessments and corresponding drainage strategies are identified on the following drawings, presented within Appendix D:

- 001 Pre-Development Drainage Strategy
- 002 Post-Development Drainage Strategy

5.2.1 Pre-Development

The pre-development site comprised a residential building with driveway, garage, gardens and a number of slabs/concrete surfaces that appear to have been historically used as outbuildings/sheds, albeit the house and outbuildings/sheds have since been demolished.

Historical topographical surveys have identified the presence of positive drainage networks (gullies/manholes etc.) at the front of the site, providing drainage infrastructure for the previous residential dwelling, driveway and garage, that discharges to the local drainage network/combined sewer. The remainder of the site (gardens/slabs etc) drains by run-off and infiltration into the ground.

The land use within the Pre-Development site has been analysed in Table 9, below.

Table 9 – Summary of Pre-Development Drained Areas

Land Use	Total Drained Area (m^2)
Impermeable Area with positive drainage, discharging to local drainage network/combined sewer	397
Impermeable Area, drained to adjacent gardens for infiltration	163
Permeable Area (gardens) drained by infiltration	518
Total	1,078

Calculations for the land uses and surface water storage are provided in Appendix E.

5.2.2 Post-Development

The post-development site consists of a set of apartments to replace the existing residential dwelling, construction of a new residential dwelling at the rear of the site, car parking and gardens that will be drained as follows.

5.2.2.1 Catchment 1

Catchment 1 is the new apartments and access road and will be drained using a positive drainage network discharging to the local drainage network/combined sewer. Prior to discharging to the network, rainfall from roof drainage will be collected in water butts for reuse. An overflow facility to the positive drainage network will be provided from the water butts to discharge excess flows when the water butts are full.

As a precautionary approach, this area will be assessed as fully impermeable, i.e. ignoring the benefits of incorporating water butts for rainwater reuse and considered as an impermeable area with a positive drainage, discharging to a local drainage network/combined sewer.

This catchment has an area of 386m^2, which is smaller than the equivalent area in the Pre-Development scenario (397m^2), with corresponding reductions in flow rates/volumes discharging to the local drainage network/combined sewer.

As the reduction in catchment area will ensure that Post-Development discharges will always be lower than Pre-Development discharges, a flow control (orifice plate) is not considered necessary and has been omitted from the proposal.

5.2.2.2 Catchment 2

Catchment 2 is located in the middle portion of the site and consists of car parking, accesses and a garden. These mixed uses generate a combination of permeable and impermeable surfacing.

5.2.2.3 Catchment 3

Catchment 3 consists of a new dwelling with a green roof and garden. The green roof will include an overflow facility that discharges to a soakaway in the garden. As a precautionary approach the green roof has been considered as fully impermeable i.e. ignoring the benefits provided by attenuation within green infrastructure and considered as an impermeable area draining to a soakaway.

5.2.2.4 Post-Development Land Use Analysis

The Post-Development land use has been developed to align, in so far as is practicable, with the Pre-Development land use, as demonstrated on Drawing 002 in Appendix D, and summarised in Table 10, below.

Table 10 – Summary of Post-Development Drained Areas

Land Use	Catchment 1	Catchment 2	Catchment 3	Total Drained Area	Pre-Development Value (Difference)
Impermeable Area with positive drainage, discharging to local drainage network/combined sewer	386m^2	0m^2	0m^2	386m^2	397m^2 (-11m^2)
Impermeable Area, drained to adjacent gardens for infiltration	0m^2	215m^2	34m^2	249m^2	163m^2 (+86m^2)
Permeable Area (gardens) drained by infiltration	0m^2	149m^2	176m^2	325m^2	518m^2 (-193m^2)
Green Roof	0m^2	0m^2	118m^2	118m^2	0m^2 (+118m^2)
Total	386m^2	364m^2	328m^2	1,078m^2	(0m^2)

In summary, the proposed development drainage areas have been assessed to comprise the same drained area as the previous development (prior to demolition).

5.3 Hydraulic Analysis

5.3.1 Catchment 1

As outlined previously, the Post-Development catchment area is slightly smaller than the Pre-Development scenario. It is therefore considered that the proposed development does not increase potential flood risk, or adversely affect the drainage infrastructure within the locale.

It is therefore proposed that attenuation is not required, as the proposed development does not create additional drainage flows to the existing pre-development scenario. However, the proposed development will include water butts at all downspouts to capture rainwater for reuse. As a precautionary approach, we have assessed the surface water storage requirements for the 100 year return period using the UK SuDS calculation tools, as included in Appendix E. This assessment identifies that for a 1 in 100-year return period, a storage volume of 13m^3 is required.

The topography of the development will dictate that these excess flows will generally drain in the direction of Catchment 2 and "flood" the car parking and garden. Assuming 50% of this area is utilised to manage these flows, this equates to a depth of water of 71mm. All door thresholds/access (or any other element significantly impacted by flooding) will be at a significantly higher level than this 71mm depth of flood water.

5.3.2 Catchment 2

As outlined previously, Catchment 2 requires drainage of 215m^2 of impermeable car park surfacing. It is proposed that this is achieved by using a ring soakaway. We have utilised the UK SuDS calculation tools, included in Appendix E, and developed a soakaway with the following properties:

- Drained area – 215m^2;
- Soakaway Dimensions – 3.5*3.5m;
- Perforated MH Ring – 2.4m diameter;
- Free Draining stone – Porosity n = 0.4;
- Infiltration Coefficient – 7.58*10^{-5}m/s (from RML Site Investigation);
- Factor of Safety – 3.

This assessment confirms that an overall soakaway height of 600mm is required to provide infiltration into the existing ground, with an approximate duration of 1.6 hours to empty 50% of the stored volume.

It is important to note that the 600mm height referenced above is the depth below the invert of the incoming drainage pipe entering the soakaway. Due to the small catchment size, and land use, the maximum depth of incoming pipe is estimated as 750mm, giving a total soakaway depth of 1.35m.

This total depth is significantly higher than the recorded ground water depth of 3.35m below ground level, or deeper, recorded during site investigation works, further justifying the proposal.

5.3.3 Catchment 3

As noted previously, a precautionary approach that ignores the benefit of the green roof in Catchment 3 is being adopted for this analysis. This determines that a Catchment 3 requires drainage of 152m^2 of impermeable roof/pathway surfacing. It is proposed that this is achieved by using a ring soakaway. We have utilised the UK SuDS calculation tools, included in Appendix E, and developed a soakaway with the following properties:

- Drained area – 152m^2;
- Soakaway Dimensions – 3.0*3.0m;
- Perforated MH Ring – 2.1m diameter;
- Free Draining stone – Porosity n = 0.4;
- Infiltration Coefficient – 7.58*10^{-5}m/s (from RML Site Investigation);
- Factor of Safety – 3.

This assessment confirms that an overall soakaway height of 560mm is required to provide infiltration into the existing ground, with an approximate duration of 1.5 hours to empty 50% of the stored volume.

It is important to note that the 560mm height referenced above is the depth below the invert of the incoming drainage pipe entering the soakaway. Due to the small catchment size, and land use, the maximum depth of incoming pipe is estimated as 600mm, giving a total soakaway depth of 1.16m.

This total depth is significantly higher than the recorded ground water depth of 3.35m below ground level, or deeper, recorded during site investigation works, further justifying the proposal.

6 Screening Assessment

6.1 Introduction

A screening process has been undertaken in accordance with the guidelines set by the Richmond Upon Thames Borough Council, and the findings are described in Table 11, Table 12 and Table 13 below.

6.2 Subterranean Characteristics

Table 11 – Subterranean Characteristics Screening

Question	Response	Details
1. Does the recorded water table extend above the base of the proposed subsurface structure?	No	Historical boreholes from the RML ground investigation recorded groundwater levels of between 3.35m bgl to 4.00m bgl. The proposed Phase 1 basement is to extend to approximately 2.60m below ground level and should be approximately 0.80m above the groundwater table (accounting for seasonal fluctuations).
2. Is the proposed subsurface development structure within 100m of a watercourse or spring line?	No	The River Thames is approximately 1200m away at its closest point. No spring lines are recorded as present within 100m of the site recorded by DEFRA, accessed using Magic Maps.
3. Are infiltration methods proposed as part of the site's drainage strategy?	Yes	It is understood that green roof spaces, rainwater butts and permeable paving may be used, as outlined in Section 5.
4. Does the proposed excavation during the construction phase extend below the local water table level or spring line (if applicable)?	No	Accounting for an over-dig of 10%, the excavation of the basement shall extend to approximately 2.86m below ground level. Groundwater is expected at depths between 3.35m to 4.00m below ground level at the site, (providing a limited account for season fluctuations in ground water level). Therefore, it is anticipated that the basement over-dig should be above the standing groundwater table at the site.
5. Is the most shallow geological strata at the site London Clay?	No	Made Ground is expected to be present at the site. Underlying this is the Langley Silt Member and the Kempton Park Gravel Member, expected at levels of 6.60m AOD and 5.00m AOD to 5.50m AOD respectively.

Question	Response	Details
		The London Clay Formation underlies these two layers of superficial deposits.
6. Is the site underlain by an aquifer and/or permeable geology?	Yes	The site is underlain by a Principal Aquifer in the Kempton Park Gravel Member. The Groundwater is classified as having a medium to low vulnerability.

6.3 Land Stability

Table 12 – Land Stability Screening

Question	Response	Details
1. Does the site, or neighbouring area, topography include slopes that are greater than 7˚ (approximately 1 in 8)?	No	The land across the site has been levelled during demolition of the previous building with a fill applied to the northeast section of the site. The site is approximately level with a previous gradient of 0.5%. Based on ordnance survey information, the neighbouring land to the site has a similar shallow gradient of approximately 0.25-0.5% towards the River Thames towards the northeast.
2. Will changes to the site's topography result in slopes that are greater than 7˚ (approximately 1 in 8)?	No	The proposed development at the site does not include any significant adjustments to the topography in the long term.
3. Will the proposed subsurface structure extend significantly deeper underground compared to the foundations of the neighbouring properties?	No	The proposed Phase 1 basement is planned to extend to approximately 2.60m below ground level and the approximately 1.5m below ground level for the Phase 2 development.
4. Will the implementation of the proposed subsurface structure require any trees to be felled or uprooted?	No	Based on the 2019 submitted arboreal planning report and recent aerial photography, there are no existing trees at the site. A small cherry tree was present at the site prior to demolition (circa early 2018).
5. Has the ground at the site been previously worked?	Yes	Demolition of the previous Victorian residential building was undertaken between circa 2017 and 2018, and the ground in the immediate area of the former dwelling and basement was infilled, based on site photographs from Google Earth historical aerial photography.

Question	Response	Details
		It is understood that the previous dwelling's basement box is still present beneath the site.
6. Is there a history of seasonal shrink-swell subsidence in the local area and/or evidence of such effects at the site?	No	The expected superficial geology at the site is the Langley Silt Member and the Kempton Park Granular Member. The Langley Silt Member is a predominantly cohesive stratum, however, based on the results of the geotechnical laboratory testing, the test results indicated the tested material to be of a low plasticity with a low volume change potential. Therefore, it is considered that the risk of shrink/swell movements within the Langley Silt Member will be low. The Kempton Park Gravel Member is a granular stratum and is therefore not expected to display shrink-swell properties.
7. Is the site within 100m of a watercourse or a potential spring line?	No	The River Thames is approximately 1200m away. No spring lines are recorded as present within 100m of the site recorded by the DFRA, accessed using Magic Maps.
8. Is the site within the vicinity of any tunnels or railway lines?	No	The closest railway line is the Teddington to Hampton Wick railway line, approximately 400m to the southwest of the site. Tunnels are not expected to be present under the site.
9. Is the site within 5m of a highway or pedestrian right of way?	Yes	The site is adjacent to the A310 Kingston Road with pedestrian right of way.

6.4 Flood Risk and Drainage

Table 13 – Flood Risk and Drainage Screening

Question	Response	Details
1. Will the proposed subsurface development result in a change in impermeable area coverage on the site?	Yes	The findings of Section 5 of this report indicate that the area of drainage ground will remain approximately the same as was present prior to the demolition of the previous Victorian dwelling.
2. Will the proposed subsurface development impact the flow profile of throughflow, surface water or groundwater to downstream areas?	No	The previous basement box is still present beneath the site. Additionally, groundwater is anticipated to be approximately 0.80m below the proposed underside of the proposed Phase 1 basement. It is therefore considered that

Question	Response	Details
		any impact to the flow profile beneath the proposed development will be low. The proposed development is not anticipated to impact surface or groundwater flow to downstream areas.
3. Will the proposed basement result in changes to the profile of the inflows (instantaneous and long-term) of surface water being received by adjacent properties or downstream watercourses?	Yes	The existing plot of land is empty and free for water to infiltrate into the ground. The findings of Section 5 of this report indicate that the area of drainage ground will remain approximately the same as was present prior to the demolition of the previous Victorian dwelling.
4. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No	Assuming that the construction of the proposed basements follows best construction practice methods, it is considered that in the long term the quality of surface water will not be affected by the proposed development.
5. Is the site in an area identified to have surface water flood risk according to either the Local Flood Risk Management Strategy or the Strategic Flood Risk Assessment or is it at risk from flooding, for example because the proposed basement is below the static water level of nearby surface water feature.	Yes	The site is located in a Flood Risk Zone 2 area as classified by the SFRA.

6.5 Summary of the Screening Process

For the subterranean characteristics screening, the basements shall be constructed to a maximum depth of approximately 2.60m below ground level. The proposed depth of the deepest basement is above the expected ground water level of between 3.35m bgl and 4.00m bgl, based on the RML ground investigation. The site is underlain by a Principal Aquifer in the Kempton Park Gravel Member, and as such the groundwater flows are expected to be of a high volume. It is expected that with groundwater lower than the proposed deepest basement, subterranean drainage pathways shall not be significantly impacted by the proposed development, particular as the existing basement box is understood to still be present beneath the site. Additionally, infiltration methods are proposed as part of the site's drainage strategy, which are proposed to comprise green roof space, permeable paving and rainwater harvesting methods (as presented in the proposed drainage strategy drawings in Appendix D). The closest downstream watercourse to the site is the River Thames located approximately 1200m to the east.

For the land stability screening, no significant slopes are expected on the site or on the neighbouring properties, nor are significant changes to the site's topography proposed as part of the proposed development. It is understood that the existing basement box is still present beneath the site, during the removal/demolition of this basement box, it is considered that there will be a low risk of ground instability within the underlying Kempton Park Gravel Member stratum. Good practice construction/demolition techniques will limit the likely instability of the removal of the basement box.

Small bushes were present at the site prior to demolition, understood to have taken place between circa July 2017 and May 2018. A small cherry tree was present at the site prior to demolition and has since been removed. However, given that the tree is anticipated to have been removed circa five years ago, it is considered that any heave movements within the shallow Langley Silt Member will have been completed, and the Made Ground (being predominately granular material) is not anticipated to be affected by heave movements. Therefore, it is not considered that the previous removal of the cherry tree will impact the proposed development.

For the flood risk and drainage screening, the development shall have an impact on the drainage pathways, as the site is currently an open plot allowing relatively free infiltration of rainwaters, however the proposed development will be similar to the development on the site prior to its demolition. Sustainable drainage systems, including green roof spaces, rainwater harvesting, and permeable paving are proposed to manage this (further outlined in Appendix D). Given that the depth to the underside of the deepest proposed basement is likely to be above the groundwater table, it is considered unlikely that the basement will have an impact on the groundwater flow paths. The surface water drainage at the site will be changed by the proposed development, however, the overall drainage area on the site is proposed to be approximately equal to the drainage areas present at the site prior to the demolition of the previous property. Further to this, the construction of a suitable SuDS drainage system will further reduce the risk of surface water ponding or flooding on the site. The site is located within a Flood Risk Zone 2, which will need to be accounted for in the design of the proposed building and basement structures.

7 Scoping Assessment

7.1 Introduction

Within this section the potential concerns that have arisen from the screening process are developed and recommendations are made to where measures should be in place or further evidence is required to reduce the impact of the development.

The following issues have been brought forward from the Screening process for further assessment:

7.2 Subterranean Characteristics

This section aims to provide further details on the potential assessments of concern from the subterranean characteristics screening assessment. Details of the individual assessments are outlined below:

3. Are infiltration methods proposed as part of the site's drainage strategy?

It is understood that various infiltration methods are proposed as part of the planning application to decrease infiltration rates at the site, including the installation of green roof spaces, rainwater harvesting measures and permeable paving. Soakaway parameters have been provided based on the testing undertaken during the RML ground investigation, and provisional soakaway locations have been provided in Appendix D. The surface water drainage at the site will be changed by the proposed development, however, the overall drainage area on the site is proposed to be approximately equal to the drainage areas present at the site prior to the demolition of the previous property.

6. Is the site underlain by an aquifer and/or permeable geology?

The site is located over a Principal Aquifer within the Kempton Park Gravel Member, which is designation with a medium-low ground water vulnerability. The proposed development is highly unlikely to significantly affect the volume of water the aquifer is capable of storing since the deepest basement is not expected to extend below the groundwater table.

7.3 Land Stability

This section aims to provide further details on the potential assessments of concern from the land stability screening assessment. Details of the individual assessments are outlined below:

5. Has the ground at the site been previously worked?

The site would initially have been worked for the construction of the basement associated with the previous Victorian dwelling. Based on site photographs from Google Earth historical aerial photography, demolition of the previous Victorian residential building was undertaken between 2017 and 2018, however, it is understood that the previous basement box remains in-situ (though is likely to have been infilled with demolition materials). The site appears to have been reprofiled during the demolition works, however, this should be confirmed by a site visit prior to the commencement of the construction works.

9. Is the site within 5m of a highway or pedestrian right of way?

The pedestrian right of way adjacent to Kingston Road shares a 15m long boundary with the site. The residential building basement is closest to this boundary at 3.25m away from the basement light well shown in drawing 195 PL(10) P00. As the site is generally level (approximately 0.5% slope), it is considered that with best practice construction techniques, the risk of land instability to the existing roads/pavements will be negligible during the basement construction process. However, this would be confirmed upon completion of the Ground Movement Assessment for the proposed basements.

7.4 Flood Risk and Drainage

This section aims to provide further details on the potential assessments of concern from the flood risk and drainage screening assessment. Details of the individual assessments are outlined below:

1. Will the proposed subsurface development result in a change in impermeable area coverage on the site?

The site is currently a vacant plot of land, and development of the site will decrease the potential infiltration areas of the site. However, the overall drainage area of the site is proposed to be approximately equal to the drainage areas present at the site prior to the demolition of the previous property, so the proposed changes are not anticipated to have a negative effect on the local surface water drainage infrastructure.

3. Will the proposed basement result in changes to the profile of the inflows (instantaneous and long-term) of surface water being received by adjacent properties or downstream watercourses?

As per the answer to question 1. Further, the installation of a soakaway drainage cell on site will further reduce the risk of surface water flooding or migration of excess surface water to adjacent properties.

5. Is the site in an area identified to have surface water flood risk according to either the Local Flood Risk Management Strategy or the Strategic Flood Risk Assessment or is it at risk from flooding, for example because the proposed basement is below the static water level of nearby surface water feature.

The site is located within a Flood Risk Zone 2 area as classified by the SFRA. Provisions for the management of surface water have been provided in Section 5 of this report. The final design of the proposed development should consider the use of watertight basement sealing, dampproof membranes and flood water barriers (if required by the Local Authority), in addition to the recommendations in Section 5 of this report.

8 Ground Movement Assessment

8.1 Geometry

The proposed development (Phases 1 and 2) has been modelled using Oasys PDisp and XDisp, soil displacement analysis software. Loading from the development applied to the soil body has been modelled using polygons with geometry derived from drawing 240 2 PL(10) P00 Rev H. The full site is modelled with both developments within a single model. The site is split into two zones, for Phase 1 and Phase 2 to represent the different ground conditions encountered across the site.

The model dimensions have been set as 71.00m x 35.30m, with the lateral boundaries located 10m away from site extents, therefore for not influencing the results. Equally, based on Boussinesq theory the rigid boundary has been set where the changes in stresses due to a square surcharge are small: this is '2xB' below ground level, where B is the basement smallest dimension, resulting on the rigid boundary being 20.00m below ground level.

The average ground level has been taken as 7.20m AOD.

The neighbouring property walls closest to the site have been modelled as displacement lines at 7.20m AOD and 5.20m AOD. The displacement lines are used as reference points to provide information about the expected deflections at the neighbouring property walls at an approximate ground level, and below ground at a level typical for a basement, should they exist. The property to the north of the site is 215 Kingston Road. The property to the south of the site, 219 Kingston Road, has two walls at proximity to the proposed buildings, which for the purpose of this report will be referred to as 219A and 219B, west and east respectively.

A grid at the ground level has been defined in order to obtain the displacements in addition to the neighbouring property boundaries.

8.2 Analysis Stages

The proposed construction sequence for the new development involves the excavation of the proposed basements (including the removal of the existing basement box beneath Phase 1) and construction of the buildings for both the residential property and eco house. The excavation will reduce the effective stress of the soil producing soil heave (in the cohesive soil layers of the Langley Silt Member and London Clay Formation), in the temporary condition, the undrained Young's Modulus parameters are used for the cohesive materials in the short term. The analysis for the excavation of the basements is provided in Analysis 1, for the short term.

For the purpose of this model, the associated heave anticipated with the demolition of the previous Victorian dwelling has not been included (however, further information on this can be found in the 2016 ByrneLooby 217 Kingston Road Phase 1 – Ground Movement Assessment Report, Report No. L586-GMA-002).

Given that the demolition and reprofiling works were completed circa five years before the time of writing, it is considered that any heave caused by the removal of the property (unloading of the soil) will have been completed.

The ground will be loaded during the construction of the buildings. This is expected to occur shortly after excavation of the basements. The long term settlements are calculated in Analysis 2 using the drained Youngs Modulus values for the cohesive materials at the site. The majority of ground movement is expected to be completed as part of Analysis 1, with the remaining residual ground movements modelled in Analysis 2.

The analysis of displacements are modelled based on the serviceability limit state, therefore any over dig is not modelled.

8.3 Analysis 1 – Short Term Movement from Excavation

It is assumed that all short term and long term movements from the demolition of the previous building have already occurred. As a result, ground displacements are zero just before the excavation works begin. Ground movements reported are only short term movements caused by the new basement excavation.

The short term displacements due to the removal of the soil layers (and Phase 1 basement box) are calculated. The total displacement is calculated with no movements calculated due to consolidation. The undrained Young's Modulus values are used due to the unloading of the ground being undertaken in the short term with construction of the proposed building occurring shortly after.

The Phase 1 basement depth is 2.6m measured from ground level to the base of the proposed floor slab, drawing reference: 195 PL(20) S01 rev D.

The Phase 2 basement depth is 1.5m measured from ground level to the base of the proposed floor slab, drawing reference: 240 2 PL(20) E01 rev A.

A negative surcharge is applied for the basement areas representing the load removal due to excavation.

The unit weight of the Made Ground removed is taken as 18kN/m^3. The removal of load is modelled at the basement level.

The existing basement slab is known to have not been removed from the ground. The basement slab is assumed to be 400mm thick and is to be removed from the ground during excavation of the residential building. The unit weight of concrete removed from the ground is taken as 25kN/m^3.

8.3.1 Analysis 1 – Unloading Information

Table 14 – Analysis 1 Unloading Summary

Building	Load (kN/m²)	Level (m AOD)
Phase 1 – Residential building basement	-46.8	4.60
Phase 1 – Additional unloading (to the above) due to removal of the existing basement slab	-2.8	5.20
Phase 2 – Eco house basement	-27	5.70

8.4 Analysis 2 – Long Term Movement from Building Construction

This second analysis represents the construction of the building after excavation and the removal of the existing basement box; therefore it adds the assumed building loads to the excavation unloads from Analysis 1. It has been assumed that the new building construction will start as soon as the excavation is finished, and the London Clay Formation remains undrained.

The Phase 1 building height is 12.10m, measured from existing ground level to the top of the soffit for the first floor. The basement depth is taken as 2.60m. The height of the second floor is 5.4m, measured from the top of the first floor soffit to the underside of the roof beam. Measurements were taken from the elevations drawing, reference: 195 PL(20) S01 rev D.

The phase 2 building height is 4.70m, measured from existing ground level to the top of the eco house. The basement depth is taken as 1.50m. Measurements were taken from the elevations drawing, reference: 240 2 PL(20) E01 rev A.

In the absence of the actual loading conditions of the proposed buildings, a typical weight of 3kN/m^3 has been assumed.

8.4.1 Analysis 2 – Loading Information

Table 15 – Analysis 2 Loading Summary

Building	Load (kN/m²)	Level (m AOD)
Phase 1 – Residential Building: Basement to first floor	44.1	4.60
Phase 1 – Residential Building: Second floor	16.2	4.60
Phase 2 – Eco House	18.6	5.70

8.5 Analysis 1 – Results

Figure 10 presents a contour plot illustrating the displacements under the Excavation loads. It represents the total displacement showing a maximum heave of up to 5.5mm under the excavated basement area for the residential property. A heave of up to 3mm is shown under the eco house.

The vertical and horizontal displacements decrease while moving away from the excavation. A maximum vertical movement of 5.5mm is noted at the excavation boundary and it becomes negligible at a distance of 10m away from the excavation.

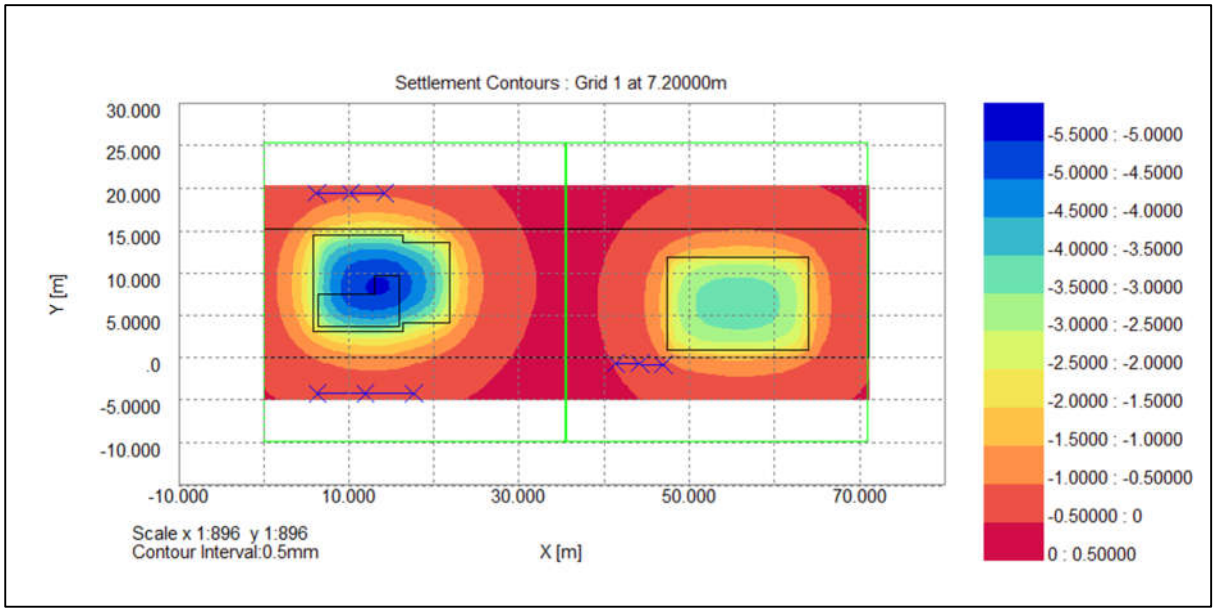


Figure 10 – Short Term Settlement from Excavation

Displacement points at the locations of the neighbouring properties have been provided. A summary of the displacements at these points is presented in the tables below. A negative value represents heaving.

As shown in Figure 10, displacements in x are positive from east to west. Displacements in y are positive from south to north.

215 Kingston Road Wall				
Length along wall from east to west (m)	Level (m AOD)	Vertical Displacement (mm)	Horizontal Displacement (δx) (mm)	Horizontal Displacement (δy) (mm)
0	7.2	-0.3	-3.1	4.3
4	7.2	-0.4	-2.0	5.5
8	7.2	-0.4	-0.4	5.7
0	5.2	-0.3	-1.1	1.5
4	5.2	-0.4	-0.7	1.9
8	5.2	-0.4	-0.2	2.0

219A Kingston Road Wall				
Length along wall from east to west (m)	Level (m AOD)	Vertical Displacement (mm)	Horizontal Displacement (δx) (mm)	Horizontal Displacement (δy) (mm)
0	7.2	-0.1	-2.4	-3.7
5.6	7.2	-0.2	-1.2	-4.5
11.2	7.2	-0.1	0.3	-4.2
0	5.2	-0.1	-0.9	-1.3
5.6	5.2	-0.2	-0.5	-1.6
11.2	5.2	-0.1	0.0	-1.5

219B Kingston Road Wall				
Length along wall from east to west (m)	Level (m AOD)	Vertical Displacement (mm)	Horizontal Displacement (δx) (mm)	Horizontal Displacement (δy) (mm)
0	7.2	0.0	0.0	-1.4
5.6	7.2	-0.1	-0.6	-1.9
11.2	7.2	-0.4	-0.9	-2.8
0	5.2	0.0	0.9	-0.1
5.6	5.2	-0.1	1.0	0.0
11.2	5.2	-0.4	1.0	0.2

In the short term, the worst-case vertical displacement expected at a neighbouring property is 0.4mm. The worst-case horizontal displacement expected is in the region of 5.7mm.

The buildings adjacent to the proposed excavation have been assessed using Oasys XDisp. The building façades are modelled as an elastic beam within XDisp with a Youngs Modulus to Shear Modulus ratio (E/G) of 2.6. Each of the building facades are modelled on their respective displacement lines. The Burland Scale is used to assess the Damage Category for each of the buildings. The model used for the analyses is displayed in Figure 11.

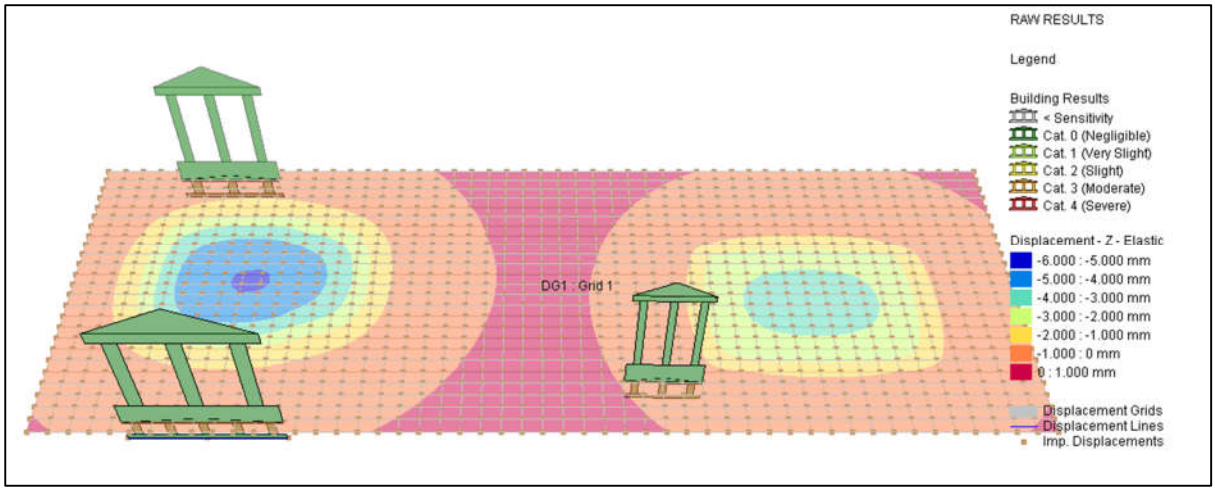


Figure 11 - XDisp Model - Short Term

The building damage assessment results for the short term are given in Table 16. The damage category provided is based on the Burland Scale of building movement assessment.

Table 16 - Building Damage Assessment Results - Short Term

Building Façade	Level (m AOD)	Critical Segment (m)	Max Settlement (mm)	Max Tensile Strain (%)	Damage Category
215	7.2	0-8	0.46	0.035	0 (negligible)
215 Basement	5.2	0-8	0.43	0.012	0 (negligible)
219A	7.2	0-11.2	0.17	0.025	0 (negligible)
219A Basement	5.2	5.6-11.2	0.16	0.008	0 (negligible)
219B	7.2	2.76-5.5	0.37	0.003	0 (negligible)
219B Basement	5.2	2.76-5.5	0.37	0.001	0 (negligible)

8.6 Analysis 2 - Results

Figure 12 presents a contour plot illustrating the displacements under the Excavation loads. It represents the total long term displacements for the site. A maximum heave of 3mm is located to the east of the eco-house, where the ground level is permanently lowered. A maximum settlement of less than 10mm is expected, at the location of the residential property, towards the centre of the building.

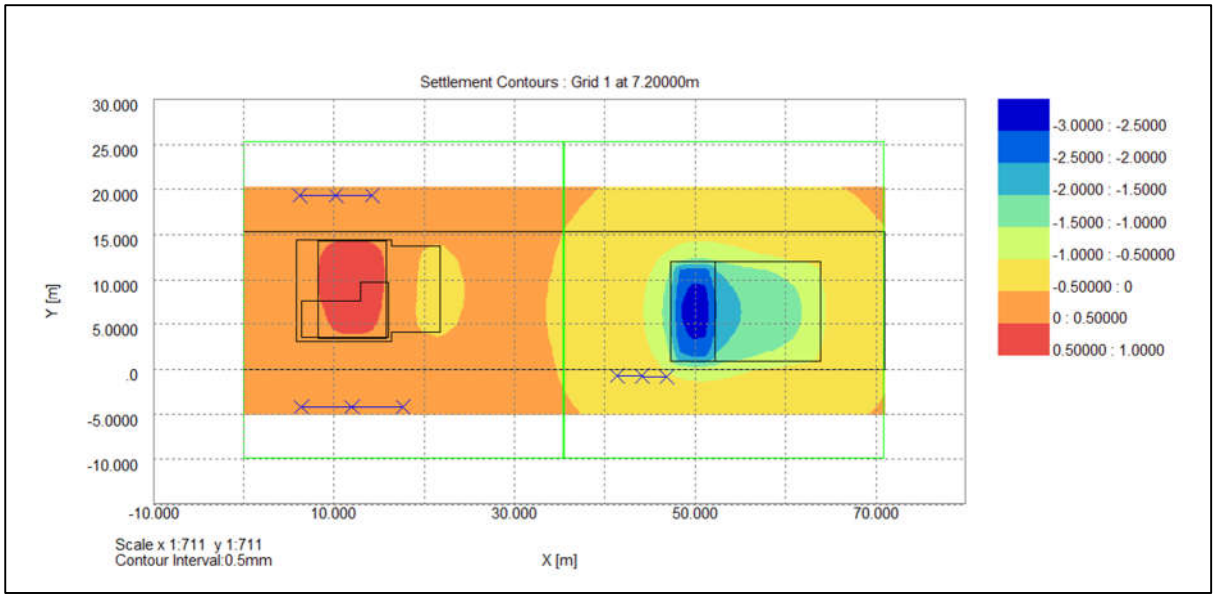


Figure 12 – Long Term Settlement from Building Construction

Similar to Analysis 1, vertical and horizontal displacements have been obtained along the neighbouring property wall locations. As shown in Figure 12, displacements in x are positive from east to west. Displacements in y are positive from south to north.

215 Kingston Road Wall				
Length along wall from east to west (m)	Level (m AOD)	Vertical Displacement (mm)	Horizontal Displacement (δx) (mm)	Horizontal Displacement (δy) (mm)
0	7.2	0.0	-0.2	-0.3
4	7.2	0.1	-0.4	-0.5
8	7.2	0.1	-0.7	-0.4
0	5.2	0.0	-0.1	-0.1
4	5.2	0.1	-0.1	-0.2
8	5.2	0.1	-0.3	-0.1

219A Kingston Road Wall				
Length along wall from east to west (m)	Level (m AOD)	Vertical Displacement (mm)	Horizontal Displacement (δx) (mm)	Horizontal Displacement (δy) (mm)
0	7.2	0.0	-0.4	0.2
5.6	7.2	0.0	-0.6	0.3
11.2	7.2	0.0	-0.8	0.1
0	5.2	0.0	-0.1	0.1
5.6	5.2	0.0	-0.2	0.1
11.2	5.2	0.0	-0.3	0.1

219B Kingston Road Wall				
Length along wall from east to west (m)	Level (m AOD)	Vertical Displacement (mm)	Horizontal Displacement (δx) (mm)	Horizontal Displacement (δy) (mm)
0	7.2	-0.1	-1.4	-0.8
2.8	7.2	-0.2	-1.6	-1.3
5.5	7.2	-0.4	-1.7	-2.3
0	5.2	-0.1	0.1	0.1
2.8	5.2	-0.2	0.2	0.2
5.5	5.2	-0.4	0.3	0.5

In the long term, the worst case vertical displacement expected at a neighbouring property is -0.4mm, representing heave. The worst case horizontal displacement expected is in the region of 3.3mm.

The buildings adjacent to the proposed construction is assessed using Oasys XDisp. The building façades are modelled as an elastic beam within XDisp with a Youngs Modulus to Shear Modulus ratio (E/G) of 2.6. Each of the building facades are modelled on their respective displacement lines. The Burland Scale is used to assess the Damage Category for each of the buildings. The model used for the analyses is displayed in Figure 13.

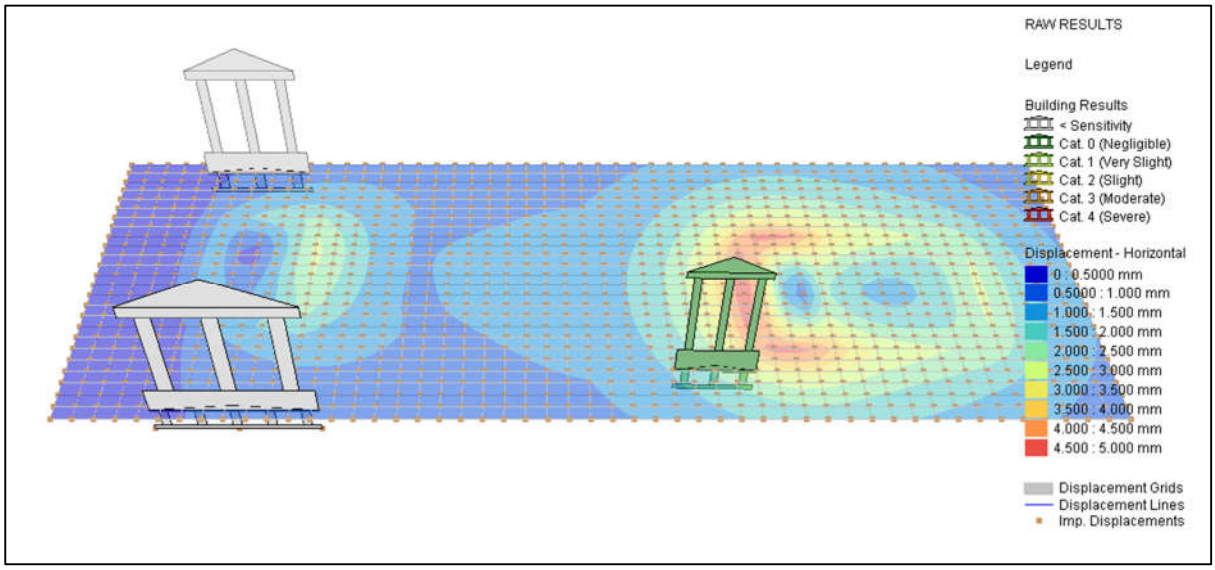


Figure 13 - XDisp Model - Long Term

The building damage assessment results for the long term are given in Table 17, below.

Table 17 – Building Damage Assessment Results - Long Term

Building Façade	Level (m AOD)	Critical Segment (m)	Max Settlement (mm)	Max Tensile Strain (%)	Damage Category
215	7.2	N/A	N/A	N/A	< Sensitivity
215 Basement	5.2	N/A	N/A	N/A	< Sensitivity
219A	7.2	2.76-5.5	0.42	N/A	0 (negligible)
219A Basement	5.2	N/A	N/A	N/A	< Sensitivity
219B	7.2	N/A	N/A	N/A	< Sensitivity
219B Basement	5.2	2.76-5.5	0.42	0.002	0 (negligible)

8.7 Conclusion of Results

The maximum horizontal displacement at a neighbouring property is at 215 Kingston Road and is expected to be 5.8mm in the short term. The maximum horizontal displacement in the long term is 2.9mm at 219B Kingston Road. The average horizontal displacements are expected to be lower, in the region of 1mm to 2mm.

It should be noted that the Boussinesq's method assumes a linear elastic, homogeneous semi-infinite space. Therefore, discontinuities in the ground may form as a result of the application of load or they may compress together. As a result, cracks are not expected to form as a result of horizontal soil movement.

Based on the assessments completed, the excavation and construction of the buildings as assessed shall have negligible effect on the neighbouring properties. With reference to Table 18, below, category 0 damage is described as the possibility of hairline cracks forming of less than 0.1mm.

Table 18 – Burland Scale

Category of damage	Description of typical damage	Approximate crack width (mm)	Limiting tensile strain εlim (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible	<0.1	0.0-0.05
1 Very slight	Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection	<1	0.05-0.075
2 Slight	Cracks easily filled. Redecoration probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weathertightness. Doors and windows may stick slightly.	<5	0.075-0.15
3 Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable lining. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5-15 or a number of cracks > 3	0.15-0.3
4 Severe	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15-25 but also depends on number of cracks.	<0.3
5 Very severe	This requires a major repair involving partial or complete rebuilding. Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion, Danger of instability.	Usually > 25 but depends on number of cracks	

9 Conclusions and Recommendations

The ground movements caused by the demolition, excavation and construction works for the proposed development have been assessed.

The soil displacements affecting the site and the surrounding area have been calculated with the soil displacement programs PDisp and XDisp, which models the soil layers elastically. The vertical loads resulting from the building loads have been applied in polygonal shapes. The assessment has been carried out for short and long term conditions.

The following conclusions can be drawn with respect to the resulting displacements.

- Neighbouring properties to 217 Kingston Road are expected to see minimal horizontal and vertical ground movements as a result of the construction works.
- The models used assume an equally distributed load across the loaded areas. This is considered to be sufficiently accurate for the assessment of displacements of neighbouring properties. Further information about the foundation sizes and loads would be required to accurately assess the settlements of the proposed buildings.
- The maximum ground displacements occur during the basement excavation phase, with maximum recorded heave movements of up to 5.5mm recorded across the central region of the Phase 1 basement dig.
- The removal of load during the excavation of the proposed basements are expected to result in a worst case horizontal ground movement of 5.8mm and vertical ground heave of 0.4mm at 215 Kingston Road in the short term. The effect of the ground movement on the 215 Kingston Road property shall be negligible, with a category 0 result assessed using the Burland Scale.
- The application of load during the construction of the proposed buildings shall reduce the heave effects observed during excavation. The construction is expected to result in a worst case horizontal ground movement of 3.3mm and vertical ground heave of 0.4mm at 219B Kingston Road in the long term. The effect of the ground movement on the worst affected property, 219B Kingston Road, shall be negligible, with a category 0 result assessed using the Burland Scale.

PDisp only allows for soil movements as a result of addition or removal of vertical loads, therefore it does not allow for movements induced by any reduction of lateral ground support during the excavation of the basement, retaining wall deflections or pile installation effects.

Based on the assessments completed, the excavation and construction of the proposed developments shall have a negligible effect on the neighbouring properties. With reference to the Burland Scale, category 0 (the anticipated worst case damage scenario to the neighbouring properties, assuming best practice construction techniques are employed) damage is described as the possibility of hairline cracks forming of less than 0.1mm.

Based on the conceptual ground model laid out within this report, with a controlled construction procedure, it is probable that the Phase 1 basement excavation shall remain dry, with the ground water level recorded below the proposed basement level in the RML ground investigation. Nevertheless, the foundation for the building may extend into the water table (as water levels have been identified at shallower depths across the local area in historical BGS borehole logs) and water control measures are recommended to be in place during excavation and construction of the building basement. Waterproofing of the basement should still be undertaken, and damp-proof membranes installed as part of the building's structure.

Due to the reduced depth of the Phase 2 basement, it is likely that the excavation of the basement and the building foundations shall not encounter groundwater, based on the RML groundwater monitoring regime and revised conceptual ground model.

The site has been divided into three catchment zones for drainage, based on permeable surface area, and use of other drainage features such as green roof spaces, rainwater harvesting and permeable paving. A soakaway drainage cell is considered to be feasible if installed within the Catchment zones 2 or 3 (the central and rear areas of the property). The drainage requirements of Phase 1 (the apartment building) are recommended to link into the existing foul and stormwater sewers, anticipated to be beneath Kingston Road.

Appendix A – Proposed Development Plans

NOTES

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FOR PLANNING

North

Site Boundary

date	rev	revision/author/checker
06.04.17	B	Site Boundary / PS / MW
27.01.17	A	Issue for planning / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
Site Location Plan

drawing no	rev
240 2 B(10)	B

drawn	PG	checked	MW
scale @ A3	1:1250	date	27.01.2017

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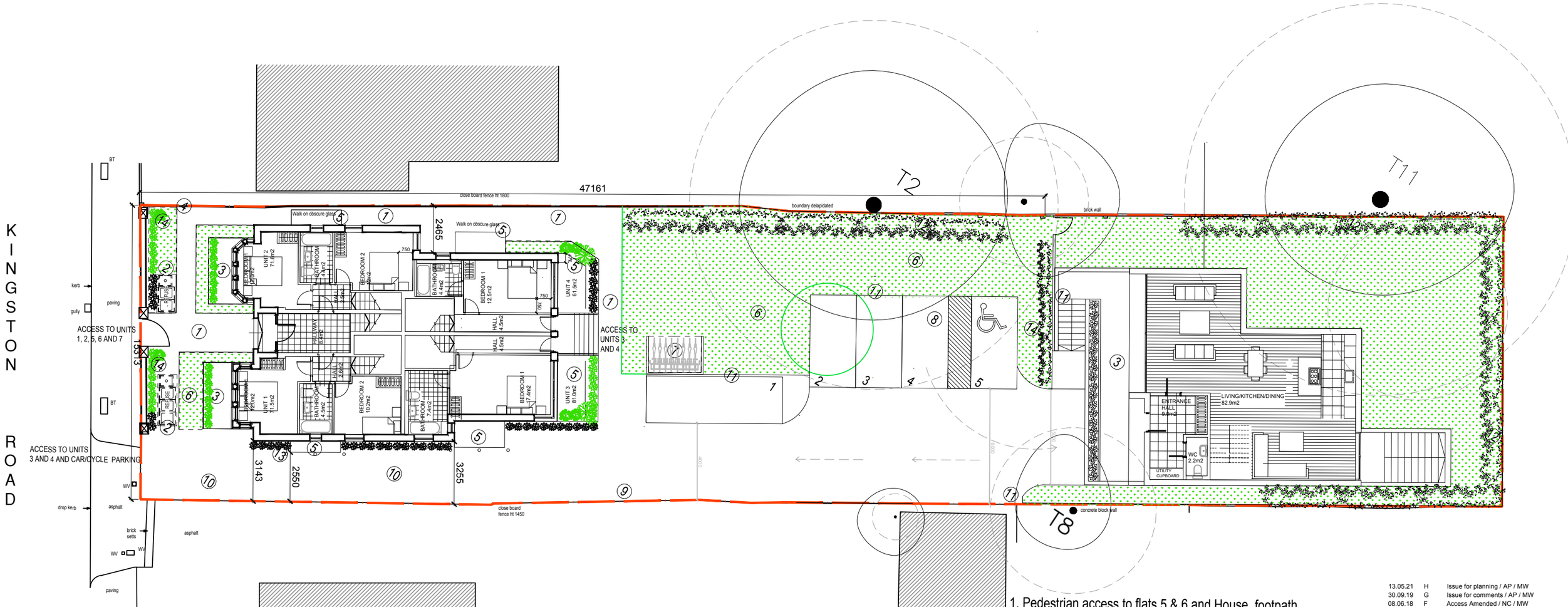

1. Pedestrian access to flats 5 & 6 and House, footpath
2. Bin store
3. Open lightwell (not covered)
4. Lightwell covered with toughened obsure glass panel
5. Lightwell/Terrace
6. Shared amenity space
7. Covered cycle parking
8. Car parking
9. Boundary
10. Vehicle access, gravel drive
11. Fence
12. Screening by Conifers (or similar planting)
13. Bollard
14. Hedge 750mm high

Scale 1:200

0 5 10 20

date	rev	revision/author/checker
13.05.21	H	Issue for planning / AP / MW
30.09.19	G	Issue for comments / AP / MW
08.06.18	F	Access Amended / NC / MW
13.05.18	E	Minor Amendment / NC / MW
23.04.18	D	Issue for planning / NC / MW
30.01.17	C	Issue for planning / PG / MW
10.11.16	B	Issue for comments / PG / MW
26.10.16	A	Issue for comments / PG / MW

client: Midco Holdings Ltd

project: 217 Kingston Road

drawing: PLANNING APPLICATION PROPOSED SITE PLAN

drawing no	rev
240 2 PL(10) P00	H

drawn	PG	checked	MW
scale @ A3	1:200	date	30.01.2017

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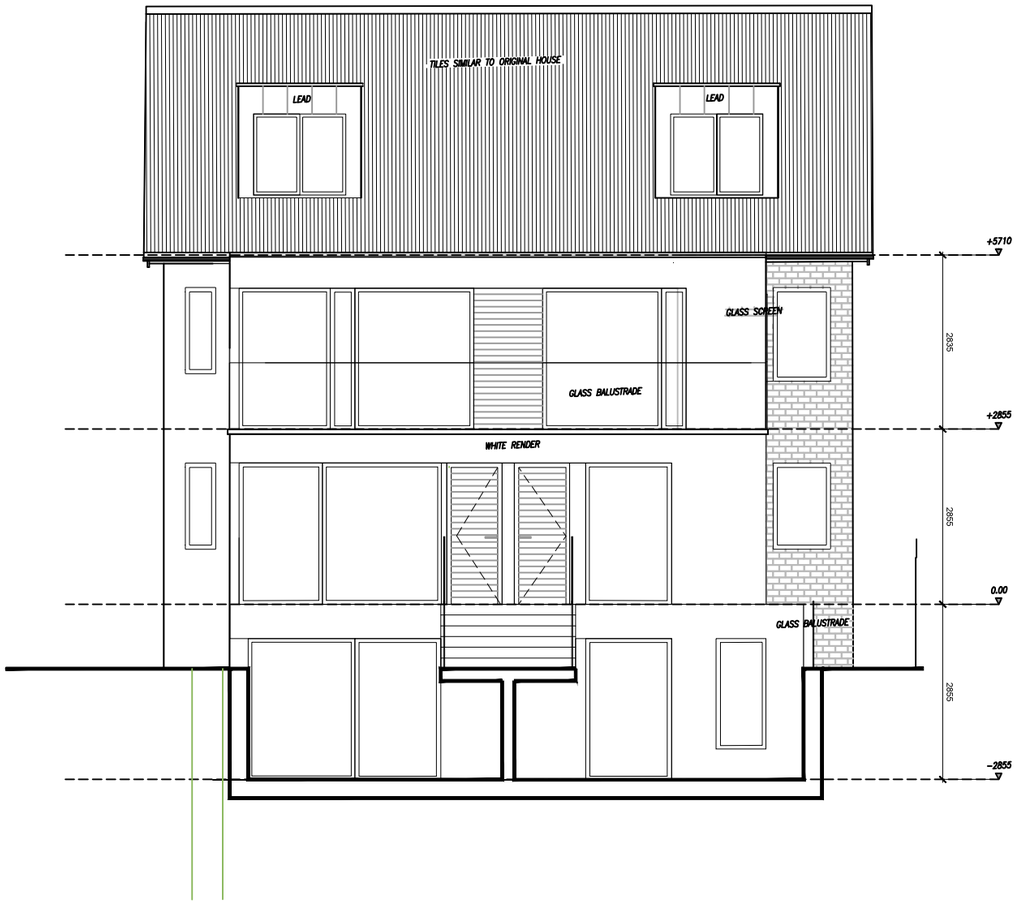

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30.09.19	I	Issue for planning / AA / MW
11.05.18	H	Minor Amendment / NC / MW
24.04.18	G	Issue for planning / NC / MW
27.01.17	F	Issue for planning / PG / MW
10.12.16	E	Issue for comments / PG / MW
03.11.16	D	Issue for comments / PG / MW
26.10.16	C	Issue for comments / PG / MW
04.10.16	B	Issue for comments / PG / MW
30.09.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PROPOSED
FRONT AND REAR ELEVATION

drawing no		rev
240 PL(20) E01		H
drawn	PG	checked MW
scale @ A3	1:100	date 27.01.2017

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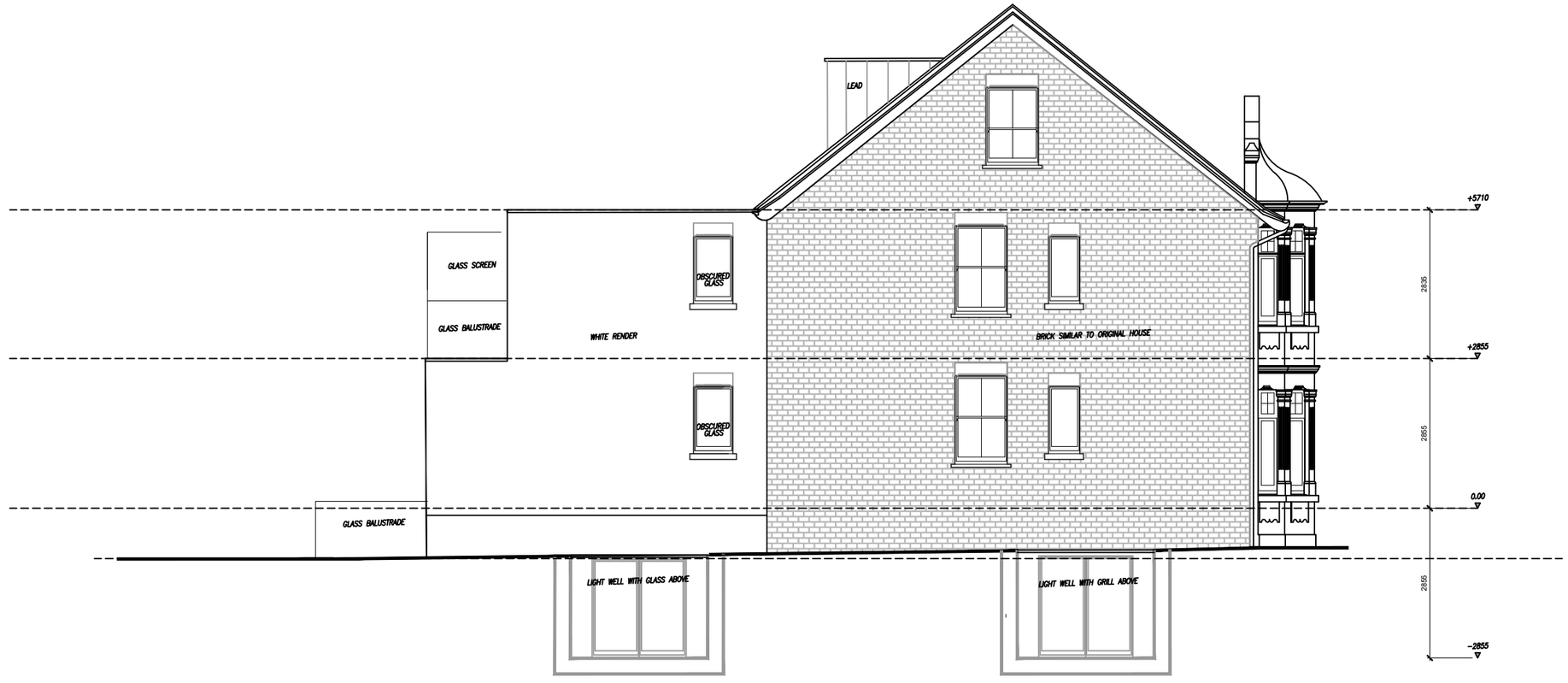

Scale 1:100

0 1 2 3 4 5 10 15

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30.09.19	G	Issue for planning / AA / MW
11.05.18	F	Minor Amendment / NC / MW
27.01.17	E	Issue for planning / PG / MW
27.01.17	D	Issue for comments / PG / MW
27.10.16	C	Issue for comments / PG / MW
04.10.16	B	Issue for comments / PG / MW
30.09.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PROPOSED
SIDE ELEVATIONS

drawing no
195 PL(20) E02

rev
H

drawn PG | checked MW

scale @ A3 1:100 | date 27.01.2017

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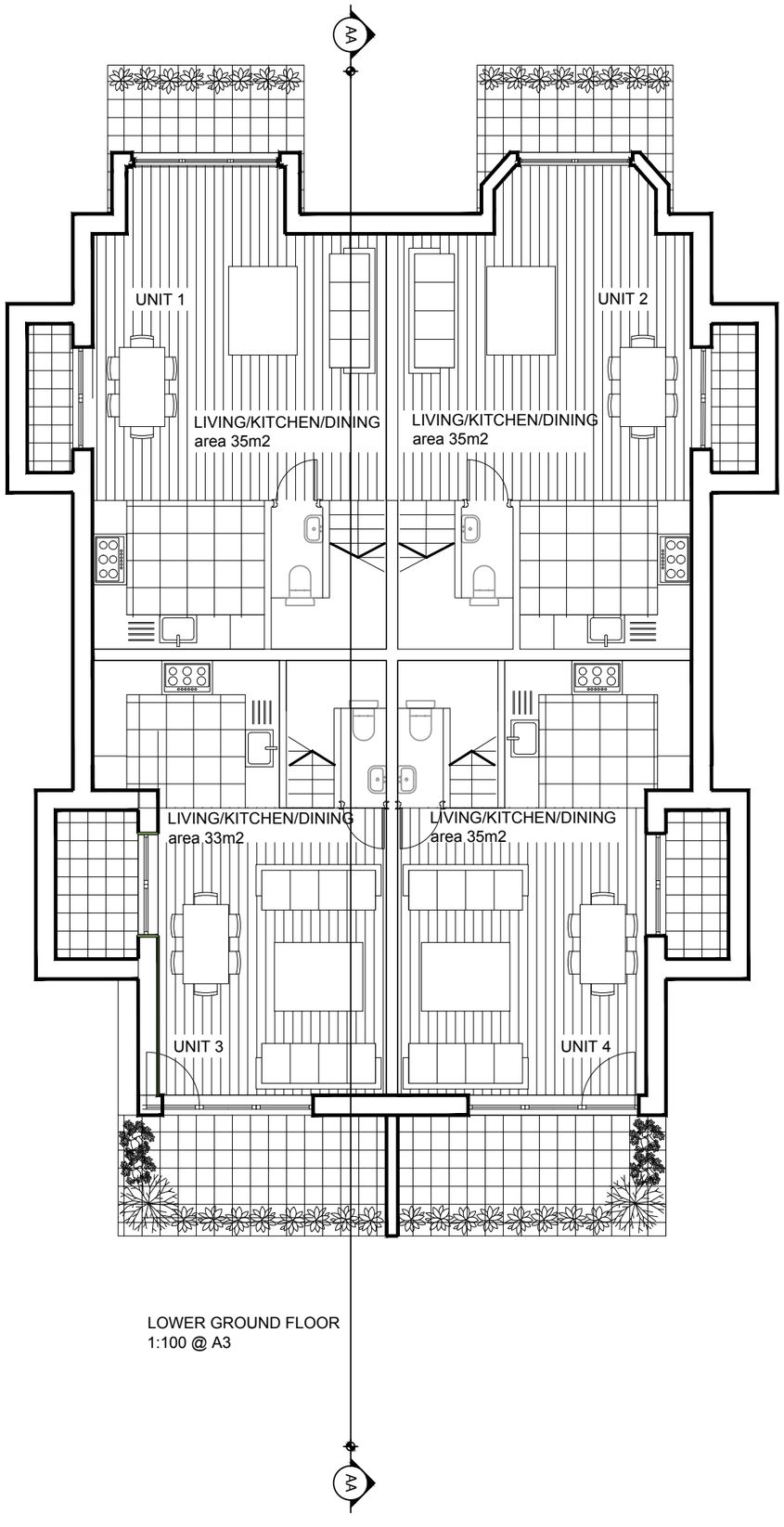

LOWER GROUND FLOOR
1:100 @ A3

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FOR PLANNING

North

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date	rev	revision/author/checker
17.09.19	I	Issue for comments / AA / MW
23.04.18	H	Issue for planning / NC / MW
27.01.17	G	Issue for planning / PG / MW
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03.11.16	E	Issue for comments / PG / MW
04.10.16	D	Issue for comments / PG / MW
22.09.16	C	Issue for comments / PG / MW
19.09.16	B	Issue for comments / PG / MW
16.09.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
LOWER GROUND FLOOR

drawing no	rev
195 PL(20) P-1	I

drawn	PG	checked	MW
scale @ A3	1:100	date	27.01.2017

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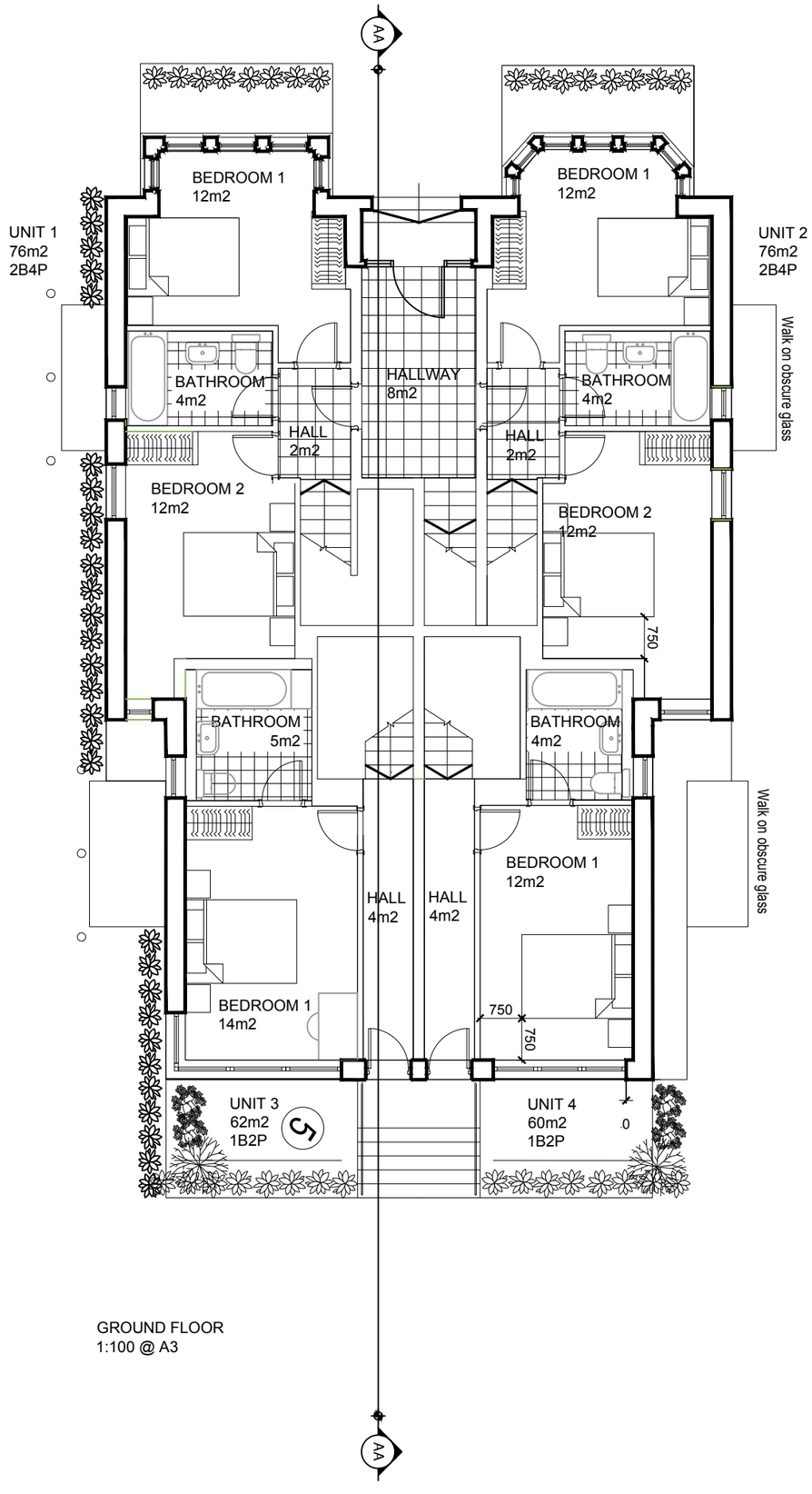

GROUND FLOOR
1:100 @ A3

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17.09.19	J	Issue for comments / AA / MW
08.06.18	I	Minor Amendment / NC / MW
26.04.18	H	Updated Area / NC / MW
23.04.18	G	Issue for planning / NC / MW
27.01.17	F	Issue for planning / PG / MW
03.11.16	E	Issue for comments / PG / MW
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19.09.16	B	Issue for comments / PG / MW
16.09.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
GROUND FLOOR

drawing no	rev
195 PL(20) P00	J

drawn	PG	checked	MW
scale @ A3	1:100	date	27.01.2017

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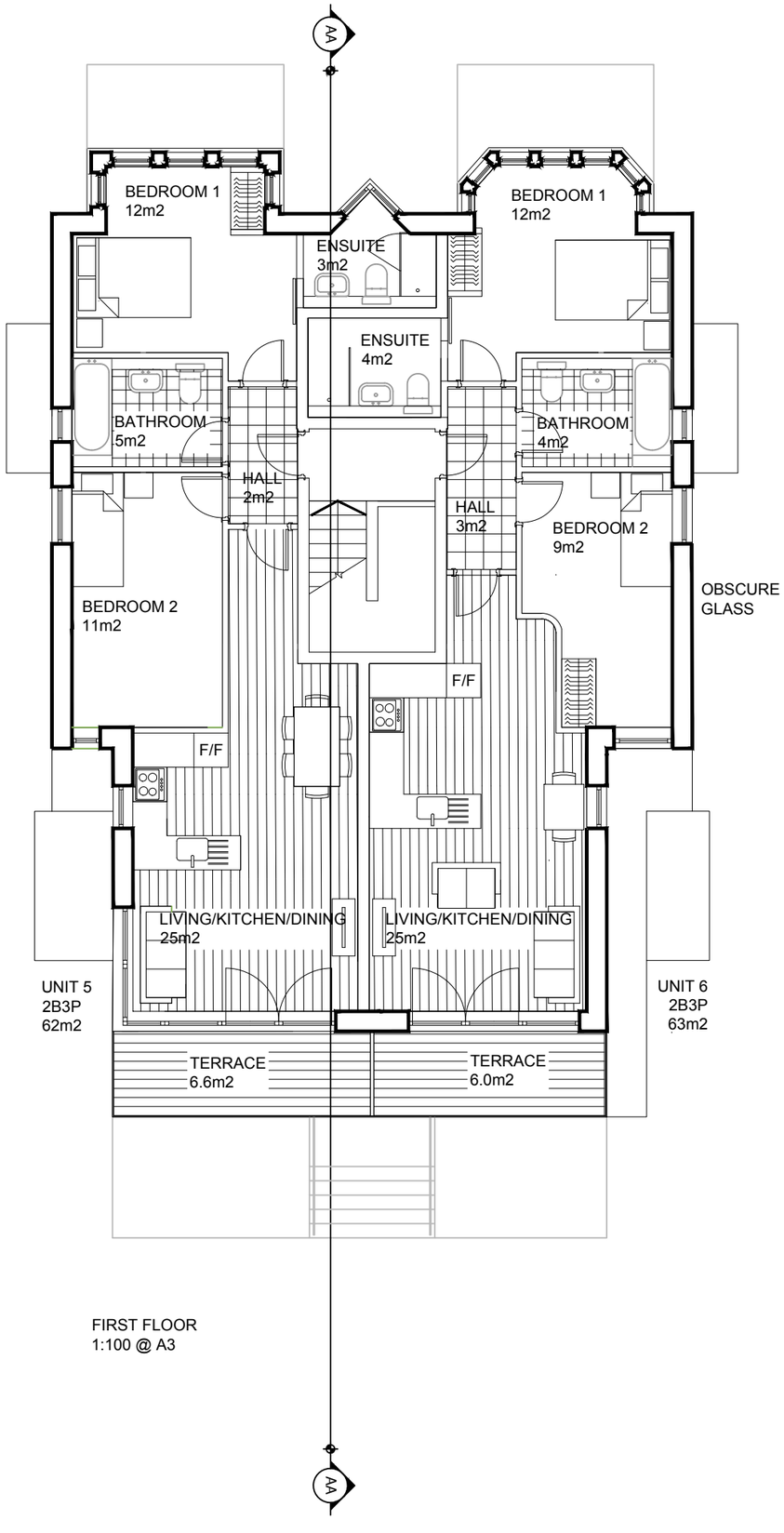

FIRST FLOOR
1:100 @ A3

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16.09.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
FIRST FLOOR

drawing no	rev
195 PL(20) P01	I

drawn	PG	checked	MW
scale @ A3	1:100	date	27.01.2017

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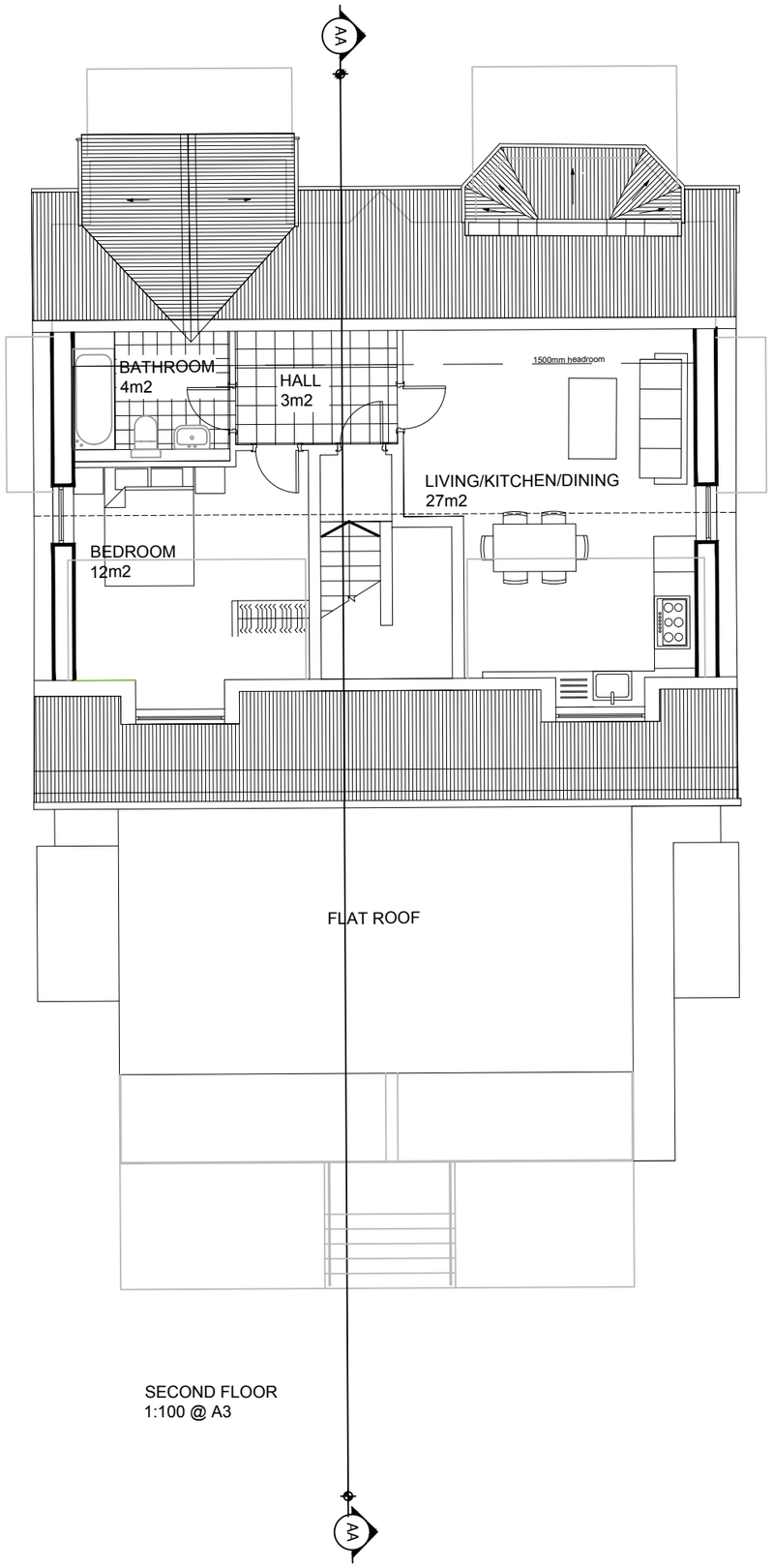

UNIT 7
1B2P
57m2

SECOND FLOOR
1:100 @ A3

Scale 1:100

0 1 2 3 4 5 10 15

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19.09.16	B	Issue for comments / PG / MW
16.09.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
SECOND FLOOR

drawing no	rev
195 PL(20) P02	I

drawn	PG	checked	MW
scale @ A3	1:100	date	27.01.2017

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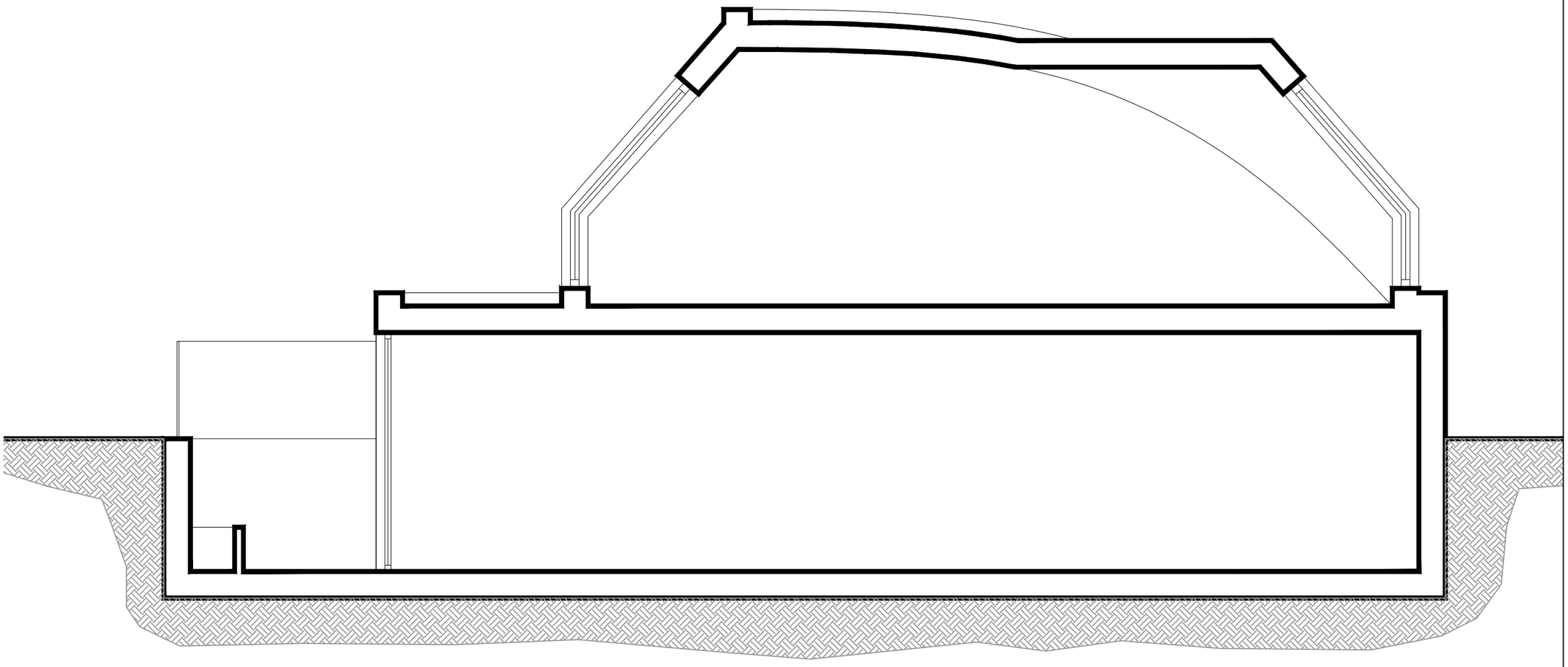

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FOR PLANNING

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30.01.17	B	Issue for planning / PG / MW
03.11.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PROPOSED
SECTION AA

drawing no	rev
240 2 PL(20) S01	B

drawn	PG	checked	MW
scale @ A3	1:100	date	30.01.2017

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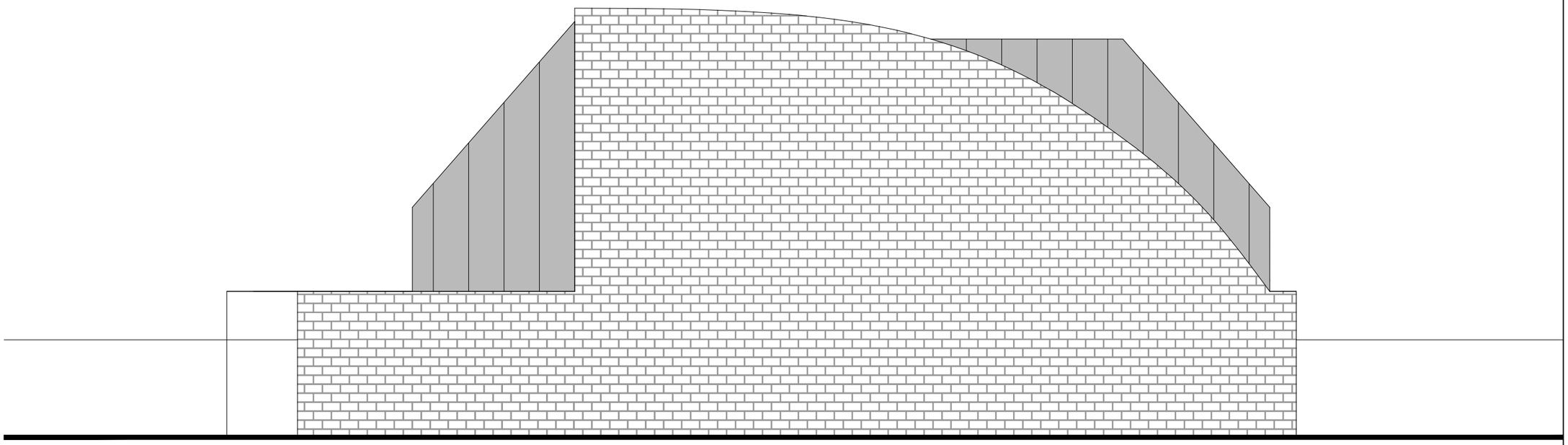

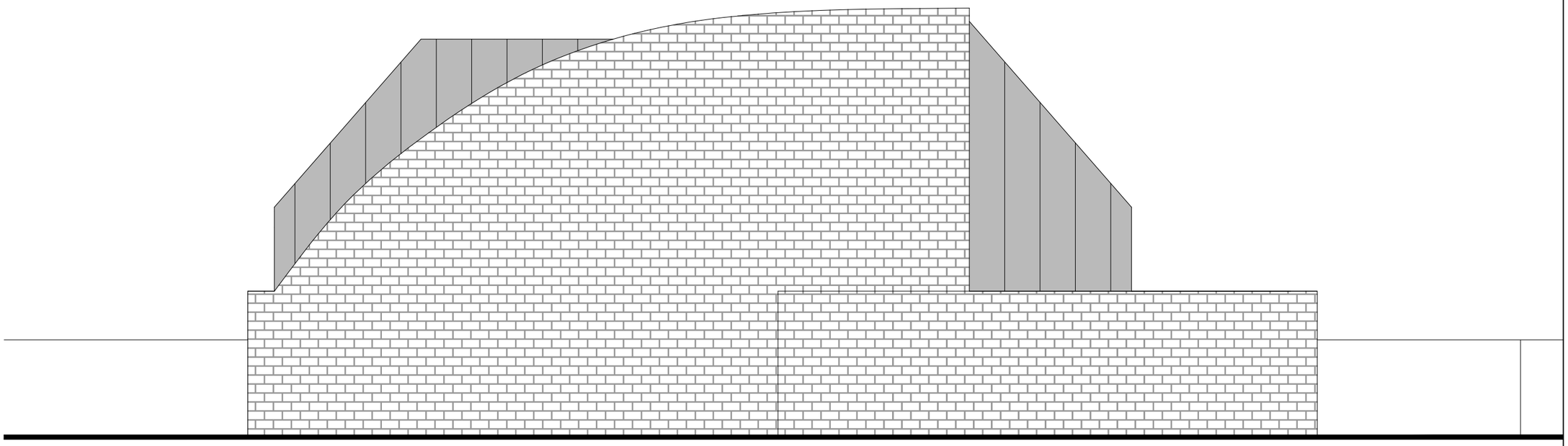

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FOR PLANNING

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30.01.17	B	Issue for comments / PG / MW
03.11.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PROPOSED
SIDE ELEVATIONS

drawing no	rev
240 2 PL(20) E03	B

drawn	PG	checked	MW
scale @ A3	1:100	date	30.01.2017

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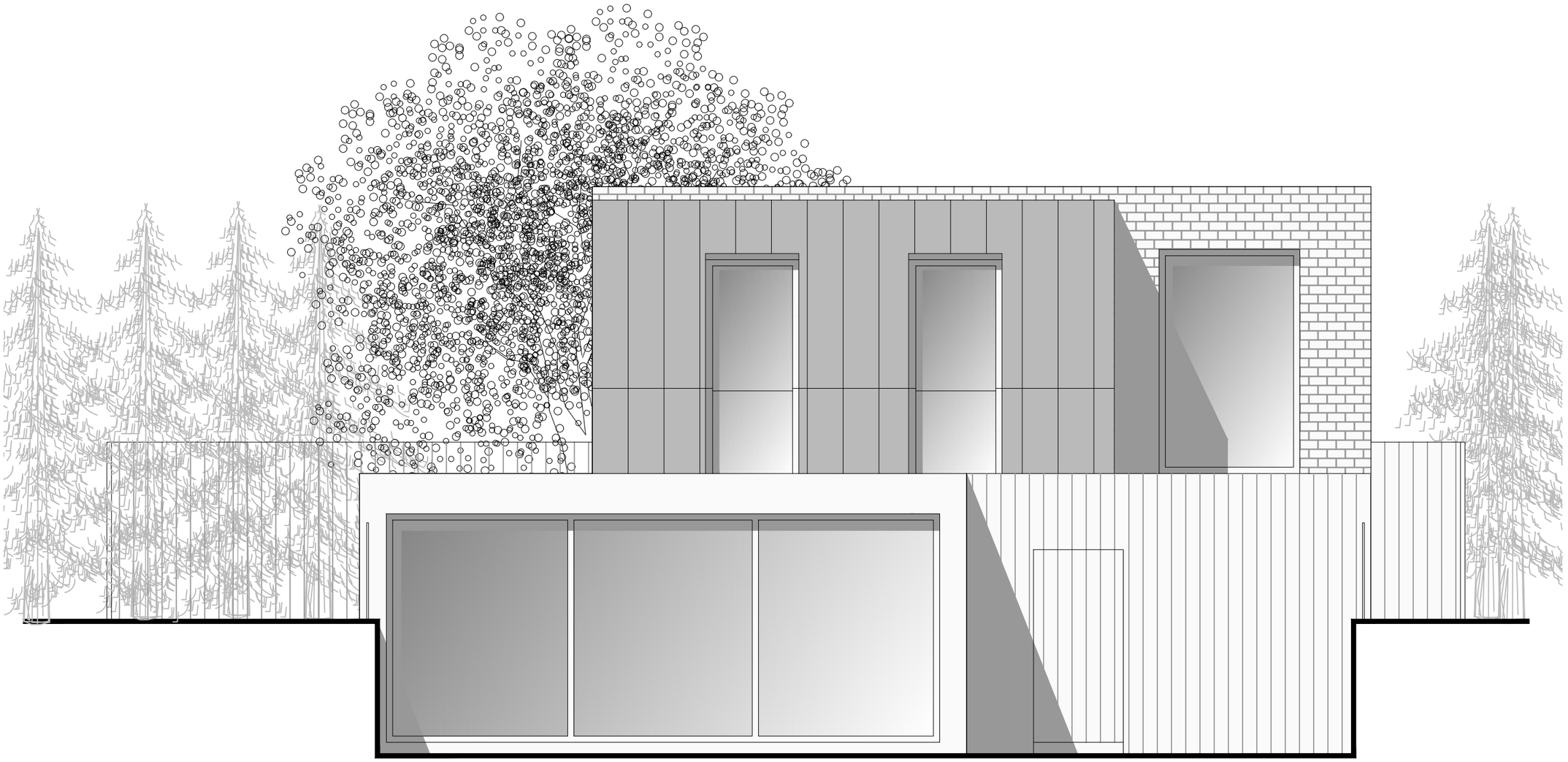

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30.01.17	C	Minor Amendment / NC / MW
30.01.17	B	Issue for planning / PG / MW
03.11.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PROPOSED
FRONT ELEVATION

drawing no	rev
240 2 PL(20) E01	C

drawn	PG	checked	MW
scale @ A3	1:50	date	30.01.2017

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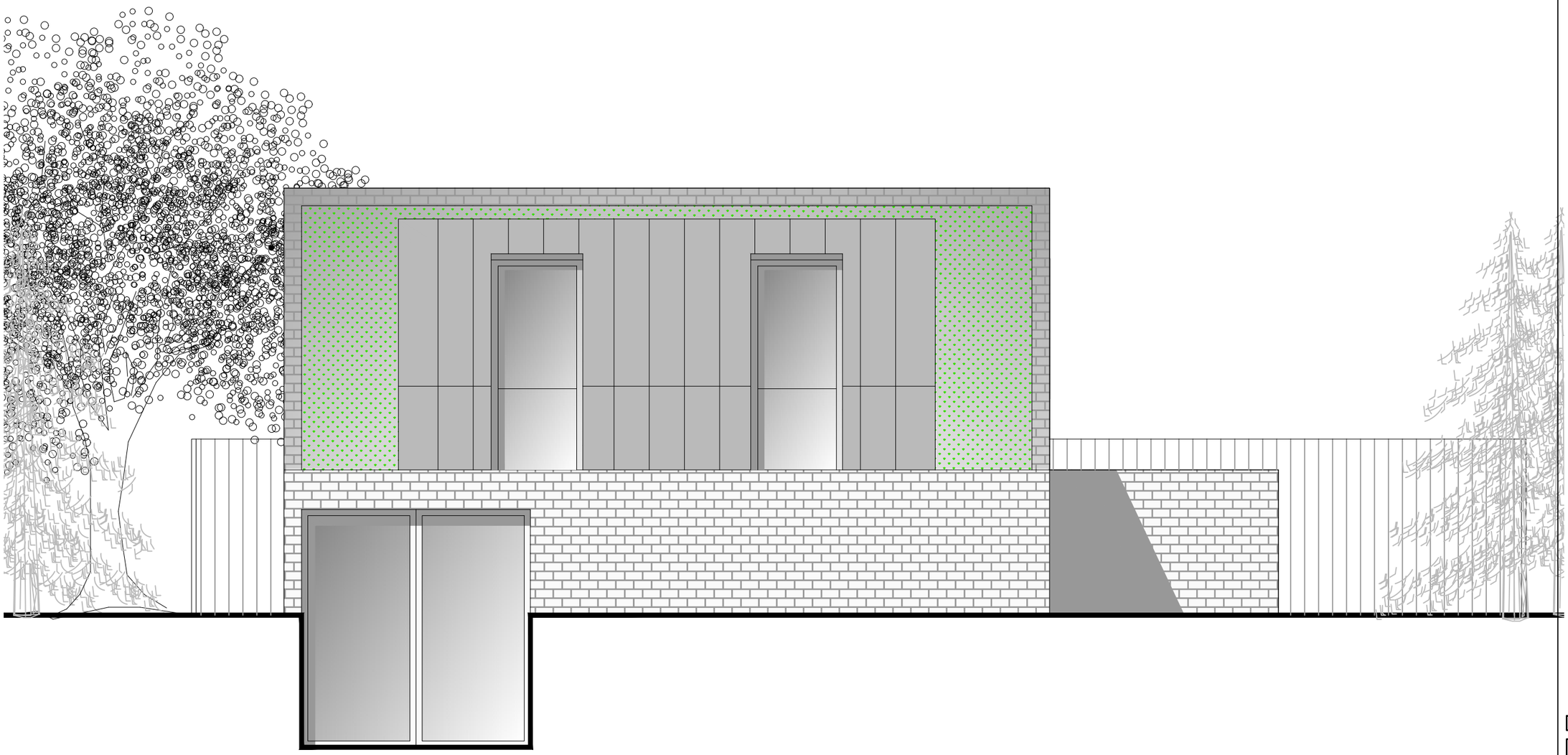

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30.01.17	B	Issue for planning / PG / MW
03.11.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PROPOSED
REAR ELEVATION

drawing no	rev
240 2 PL(20) E02	C

drawn	PG	checked	MW
scale @ A3	1:100	date	30.01.2017

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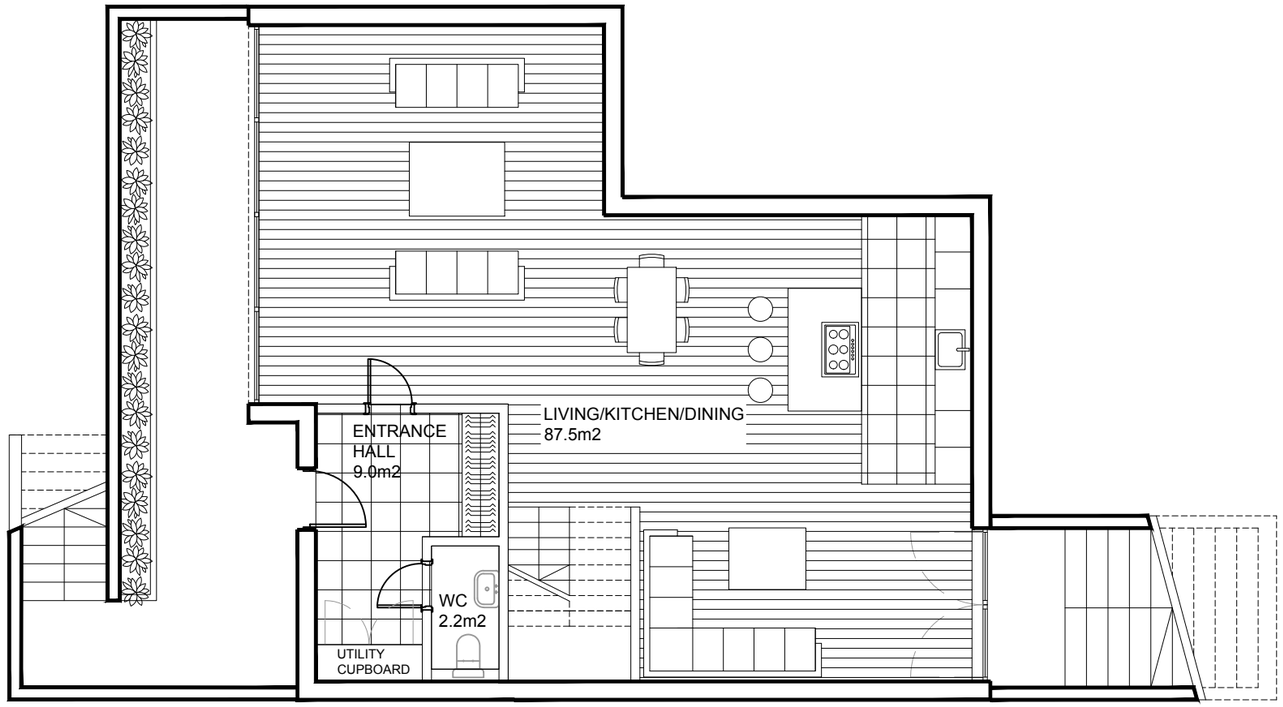

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FOR PLANNING

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25.04.18	C	Issue for planning / NC / MW
30.01.17	B	Issue for planning / PG / MW
26.10.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
LOWER GROUND FLOOR

drawing no	rev
195 2 PL(20) P-1	C

drawn	PG	checked	MW
scale @ A3	1:100	date	30.01.2017

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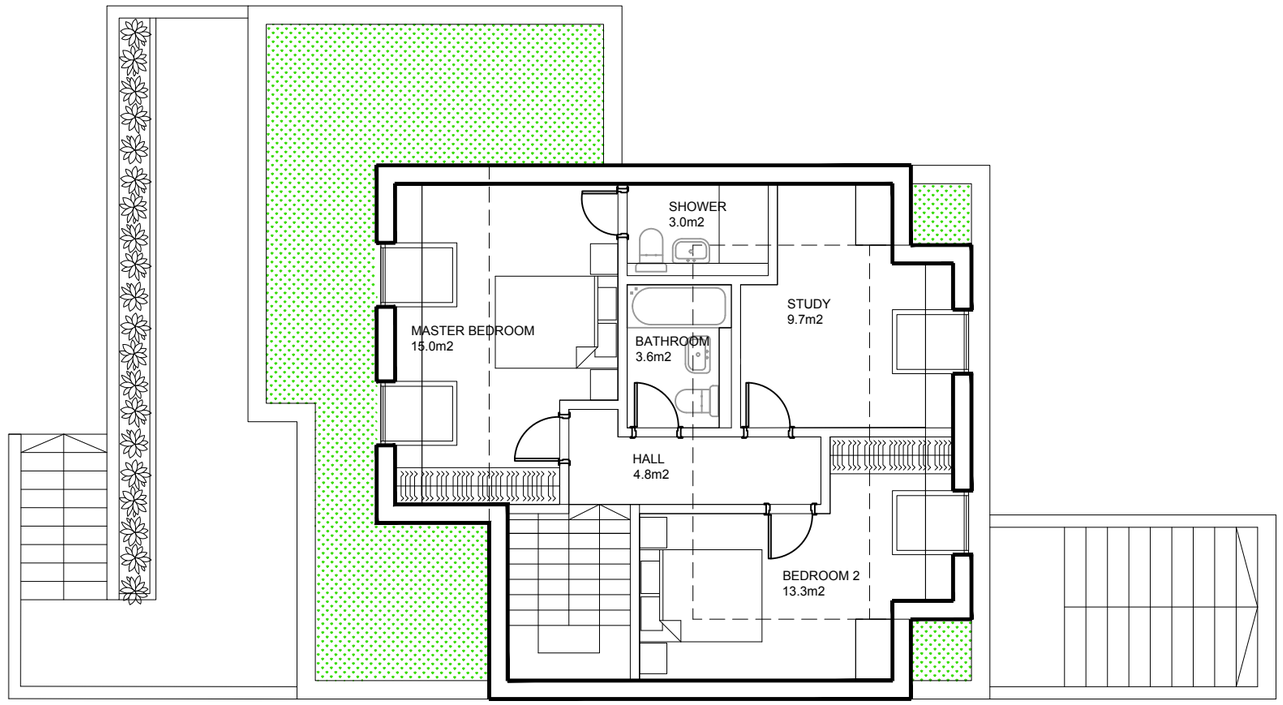

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FOR PLANNING

North

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25.04.18	C	Issue for planning / NC / MW
30.01.17	B	Issue for planning / PG / MW
26.10.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

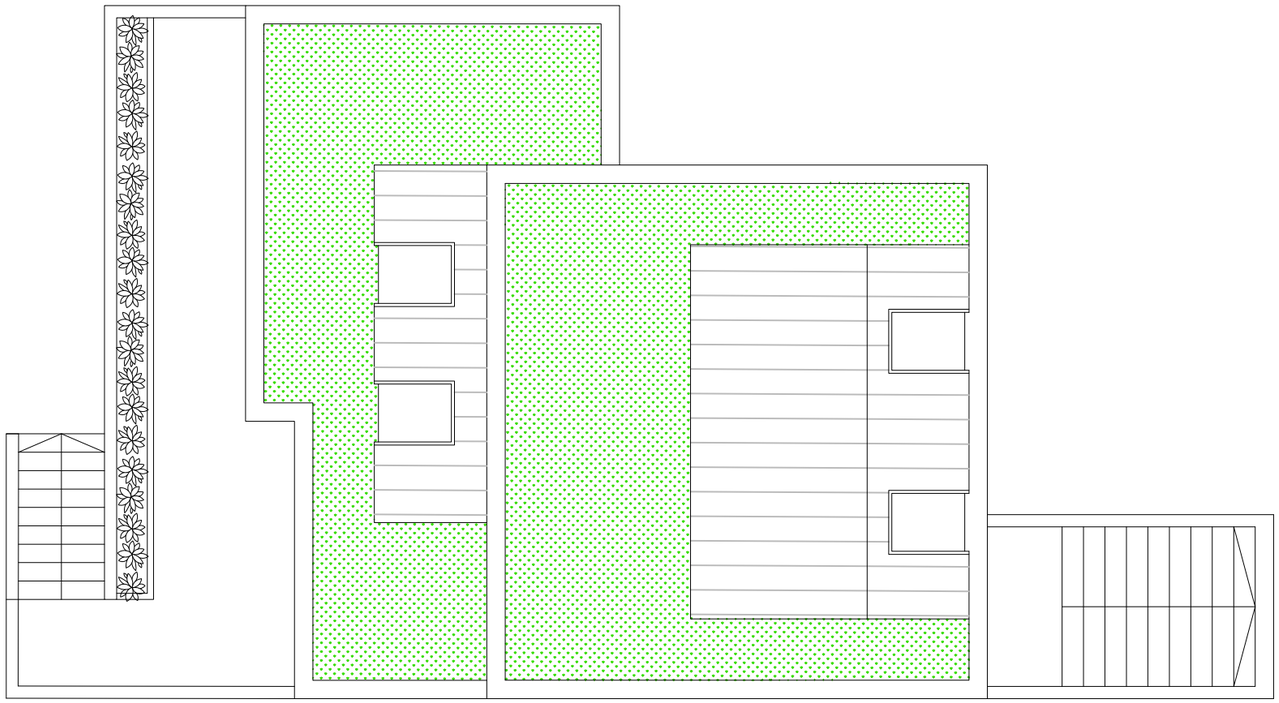
project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
GROUND FLOOR

drawing no	rev
195 PL(20) P00	D

drawn	PG	checked	MW
scale @ A3	1:100	date	30.01.2017

CREATE
DESIGN + ARCHITECTURE
Wigglesworth House,
69 Southwark Bridge Road,London SE1 9HH
T: +44 (0)20 7021 0267
www.createdesign.org



NOTES

- The Copy right of this drawing is the property of Create and must not be copied otherwise reproduced without written consent.
- The contractor is responsible for checking dimensions, tolerances and references. Any discrepancy to be verified with the Architect before proceeding with the works.
- Do not scale drawing. Figured dimensions to be worked to in all cases.

FOR PLANNING

North

date	rev	revision/author/checker
25.04.18	C	Issue for planning / NC / MW
30.01.17	B	Issue for planning / PG / MW
26.10.16	A	Issue for comments / PG / MW

client
Midco Holdings Ltd

project
217 Kingston Road

drawing
PLANNING APPLICATION
PROPOSED
FIRST FLOOR

drawing no		rev
195 PL(20) P01		C
drawn	PG	checked MW
scale @ A3	1:100	date 30.01.2017

CREATE
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Appendix B – Risk Management Limited Reports

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Godalming, Surrey GU8 5SZ
Tel: 01883 343572
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Web: www.riskmanagementltd.co.uk

22nd February 2022 MSP/RML 6259

Byrne Looby
Abbot House
Pilgrims Court
Sydenham Road
Guildford
Surrey GU1 3RX

Dear Sirs,

SITE INVESTIGATION REPORT No. RML 6259, dated December 2016.
(The Report)

AT

217 KINGSTON ROAD, TEDDINGTON TW11 9JN
(The Site)

We confirm that Byrne Looby and their successors in title may use and rely on the above noted Report prepared by us as if it had originally been prepared for them and had been addressed to them.

We confirm that in the preparation of the Report we have exercised all the reasonable skill and care to be expected of an experienced and competent geotechnical consultant.

The copyright in all documentation produced by us in relation to the Site shall be retained by us, but we hereby grant Byrne Looby and its successors in title an irrevocable, royalty free, non-exclusive licence to copy, use, adapt and reproduce the same, in any format including electronic format, for any purpose related to the Site. We will not be liable for any use of the documentation for any purposes for which they were not prepared.

We shall maintain professional indemnity insurance to cover our liability in an amount of not less than £1,000,000 for "any one accident and in all" provided such insurance is available in the open market at commercially reasonable rates for a period of 6 years from the original date of issue of the report, as noted above.

yours faithfully,
for RISK MANAGEMENT LIMITED

Malcolm S. Price B.Sc., M.Sc., M.I.C.E., C.Eng. M.I.Env.Sc.
Director

This file has been converted from its original format for security purposes. Please use C2BFA346A34C8 as a reference.

APPENDIX 1

KEY PLAN & RESULTS OF SITE INVESTIGATION WORKS

AT

217 KINGSTON ROAD TW11 9JN

Unit 8, Paddock Barn Farm
Godstone Road, Caterham,
Surrey CR3 6SF
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PROJECT No. RML 6259

SITE INVESTIGATION
AT
217 KINGSTON ROAD, TEDDINGTON

ON BEHALF OF
MIDCO HOLDINGS LIMITED

December 2016

CONTENTS

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3.0 GROUND CONDITIONS

4.0 LABORATORY TESTING

5.0 DISCUSSION

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- *Percussion Borehole Records (BH1-BH3)*
- *SPT versus Depth Profile*
- *Falling Head Test Record Sheets*
- *Particle Size Distribution Test - Sieve 1*
- *Laboratory Test Results*
- *C_u Versus Depth Profile*
- *Groundwater/Gas Monitoring Sheet*
- *Sketch Fieldwork Location Plan, Drawing No. RML 6259/1*

1.0 INTRODUCTION & SCOPE OF WORKS

1.1 This report has been prepared by Risk Management Limited to the instructions of the Consulting Engineers for the project, Messrs. Michael Bailey Orla Kelly (MBOK), under cover of their e-mailed instructions to proceed, dated 14th November 2016.

1.2 The Client for the work is Midco Holdings Ltd.

1.3 The site under consideration was No. 217 Kingston Road, Teddington, Middlesex TW11 9JN.

1.4 The current work was commissioned to provide information on the sub-soil conditions at this site, together with laboratory testing, in order to provide information on subsequent foundation design by others.

1.5 It is understood that the development of the site includes demolition of the existing building followed by construction of a new, detached, three-storey building including a full height basement to house seven apartments with an external car parking area.

1.6 This report presents the work carried out and discusses the findings.

2.0 FIELDWORK

2.1 All fieldwork was generally executed in accordance with the recommendations given in British Standard BS 5930:2015, "Code of Practice for Ground Investigations".

2.2 Borehole locations are shown on the appended Sketch Fieldwork Location Plan, Drawing No. RML 6259/1.

2.3 Fieldwork was undertaken between the 21st and 23rd November 2016 and comprised the following:-

Percussion Boreholes

2.4 Three percussion boreholes (BH1-BH3) were drilled to depths of 7.00m, 8.00m & 9.00m below existing ground level, respectively.

2.5 The drilling rig used was a Premier tracked drive-in-sampler rig which includes a 98mm diameter casing system driven into the ground with a series of 1 metre long metal tubes, varying in diameter from 80mm down to 35mm, driven through the casing to obtain disturbed samples at regular depth intervals.

2.6 Small disturbed samples were taken at regular depth intervals down each borehole.

2.7 Standard Penetration Tests (SPT) were carried out within each borehole in order to provide information on the consistency of the material encountered. The appended SPT versus Depth Profile plots the 'N' values against depth at this site.

2.8 Upon completion of boreholes BH1 and BH3 combined groundwater/gas monitoring standpipes were installed to depths of 4.60m and 5.00m below existing ground level, respectively. The monitoring installations comprised a 1 metre length of plain 50mm diameter HDPE pipe followed by slotted geotextile wrapped HDPE pipe, capped at the base. A cement/bentonite seal was installed from 1.00m to ground level and the installation was finished with a gas valve on top of the pipe and a lockable stopcock cover concreted in flush with ground level.

2.9 Full details of the percussion borehole findings are given on the appended borehole record sheets.

Land-borne Gas Monitoring

2.10 Following the initial site work, three return gas/groundwater monitoring visits were undertaken to the installations fitted within boreholes BH1 and BH3 on the 28th November 2016, 6th December 2016 and 12th December 2016.

2.11 On each visit the barometric pressure was recorded together with the level of Carbon Dioxide, Oxygen and Methane. In addition, gas flow measurements were taken and the depth to groundwater recorded.

2.12 Full details of the readings are included on the appended Gas/Groundwater Monitoring Record Sheet.

Falling Head Permeability Tests

2.13 Falling Head Permeability Tests were carried out in the standpipes installed in boreholes BH1 & BH3 at 3.35m and 3.50m below existing ground level, respectively.

2.14 The permeability tests undertaken at this site were falling head tests undertaken in accordance with B.S. 5930:1999 Part 25.4.3 Variable Head Test.

2.15 Full details are given on the attached summary sheets together with any assumptions made to obtain the permeability of the material tested and to help assess the drainage potential of the ground for proposed soakaways.

3.0 GROUND CONDITIONS

3.1 According to information published by the British Geological Survey (Sheet 270, South London) the underlying geology at this site is shown as being Recent Kempton Park Gravel (River Thames Terrace Gravel) overlying London Clay of the Eocene Period.

3.2 River Thames Terrace Deposits generally comprise primarily gravels and sand sourced from varying materials within the rivers local catchment area. These Pleistocene deposits are widespread within the London Basin and occur typically as terraces on the valley sides. These terraces represent ancient floodplain deposits that have become isolated as the river has cut downwards to lower levels.

3.3 It is thought that the London Clay formation was deposited during a period of sea inundation in the area up to 200m in depth. The London Clay can be up to 150m thick beneath south Essex thinning across London to about 90m near Reading. The formation consists of mainly dark blue to brown grey clay containing variable amounts of fine-grained sand and silt. London Clay generally weathers to an orange-brown colour with pockets of silty fine sand. The formation is particularly susceptible to swelling and shrinking when subjected to moisture content changes. In addition, gypsum (selenite) crystals and pyrite nodules are commonly found throughout the formation.

3.4 Full details of the ground conditions encountered are presented on the borehole records appended to this report and can be summarised as follows:-

Depth From (m)	Depth To (m)	Description
0.00	0.05/0.20	Topsoil (BH1 & BH3 only)
0.00/0.20	0.40/1.10	MADE GROUND
0.40/1.10	1.30/2.20	Superficial Clay
1.30/2.20	5.70/8.80	Kempton Park Gravel
5.70/8.80	9.00 +	London Clay

3.5 Groundwater was encountered during boring within all three boreholes (BH1-BH3), at 4.00m, 3.50m and 3.60m below ground level, respectively. The groundwater was found to have fluctuated to between 3.35m and 3.90m for BH1 and between 3.50m and 3.60m for BH3 during the three return monitoring visits.

4.0 LABORATORY TESTING

4.1 The following geotechnical laboratory tests have been carried out on samples recovered from the boreholes at this site.

4.2 Unless otherwise stated, the geotechnical tests have generally been carried out in accordance with the recommendations given in British Standard 1377:1990, "Methods of Test for Soils for Civil Engineering Purposes".

4.3 *Natural Moisture Content Tests*

The natural moisture content has been determined for a total of five samples of the clay found within all three boreholes and was found to range between 5% and 25%.

4.4 *Atterberg Limits*

The Atterberg Limits have been determined for one sample of the Superficial Clay from 1.50m depth in borehole BH1 and one sample of the London Clay from 6.50m depth in borehole BH1.

The liquid limits (LL) were 23% and 59%, the plastic limits (PL) 11% and 24%, and the plasticity index (PI) 12 and 35.

These results indicate that the Superficial Clay can be classified as a clay of 'low' plasticity (CL) and the London Clay as a clay of 'high' plasticity (CH) in accordance with the Casagrande Geotechnical classification system.

In addition, the Superficial Clay tested would be classified as having a 'low' potential for swelling/shrinking and the London Clay as having a 'medium' potential for swelling/shrinking, all in accordance with the National House Building Councils (NHBC) classification system given in Part 4 of their Standards.

4.5 *Quick Undrained Triaxial Compression Tests.*

The undrained shear strength has been determined in single-stage triaxial compression for four, re-moulded, 38mm diameter samples.

The resulting mean shear stress (undrained cohesion) C_u values varied between 170 kN/m^2 and 223 kN/m^2 indicating that the samples tested were 'very stiff' in consistency. Full results are plotted on the appended C_u versus Depth Profile.

4.6 *Particle Size Distribution*

The particle size distribution has been determined for one sample of the more granular soils encountered.

The results are presented as grading curves in the appendix to this report.

4.7 *pH and Sulphate Tests*

The pH and sulphate content has been determined for three samples recovered from each borehole at 2.00m below existing ground level and tested.

The pH was found to be 4.8, 6.6 and 7.6 and the sulphate content, on a 2:1 water:soil extract, 0.20 g/l, <0.02 g/l and 0.03 g/l.

5.0 DISCUSSION

PROPOSED DEVELOPMENT & SCOPE OF WORKS

5.1 As discussed in Section 1 above, it is understood that the existing property will be demolished and a new, detached, three-storey building constructed, including a full height basement to house seven apartments with an external car parking area.

5.2 The current work was commissioned to provide information on the sub-soil conditions at this site, together with laboratory testing, in order to provide information for subsequent foundation design by others.

FOUNDATION DESIGN

5.3 Beneath Topsoil in boreholes BH1 and BH3 and from ground surface in borehole BH2, MADE GROUND was in evidence up to a depth of between 0.40m and 1.10m, where a thin band of Superficial Clay up to 1.30m and 2.20m depth was encountered. Below the Superficial Clay, Kempton Park Gravel was encountered up to 5.70m and 8.80m depth, overlying London Clay. The London Clay was not penetrated at the maximum borehole termination depths of between 7.00 and 9.00m below existing ground level. SPT 'N' values tend to indicate that the Kempton Park Gravel was initially 'very loose' below the groundwater table at between 3.50m and 4.00m depth. SPT 'N' values below this depth were not able to be obtained owing to the SPT tools catching the casing and bringing it up.

5.4 For conventional strip or pad foundations, set below any MADE GROUND within the top of the underlying Superficial Clay, at a minimum depth of some 1.00m below existing ground level, an allowable bearing pressure of 100 kN/m^2 could be adopted. This could be increased to some 125 kN/m^2 at approximate basement level of around 3 to 3.5 metres below existing ground level.

5.5 Settlement due to the above noted order of loading would not be expected to exceed 20-25mm.

5.6 The results of the Atterberg Limit tests indicate that the Superficial Clay at this site would have a 'low' potential for swelling/shrinking and the London Clay at this site would have a 'medium' potential for swelling/shrinking in accordance with the NHBC guidelines. In addition, the Kempton Park Gravel would be considered to be 'non-shrinkable'. Therefore, remedial measures would probably not be required against shallow foundation sides or basement walls at this site where they fall within the zone of influence of existing trees or any proposed trees.

5.7 From the evidence of the boreholes, shallow foundation or service excavations in the MADE GROUND may require support against collapse of sides and and basement excavations in the Kempton Park Gravel will require support in the short term and we recommend that a contingency is made for this at this stage.

5.8 Groundwater was encountered during boring at between 3.50m and 4.00m depth and during the return monitoring visits as high as 3.35m depth. Groundwater may be encountered towards the base of basement excavations. Therefore, it is important that the base of excavations are kept dry by, for example, pumping from a sump, the foundation base is kept square and that any soft spots are replaced and compacted prior to pouring foundation concrete.

5.9 Further, we recommend that where seasonal groundwater or surface water flows into foundation excavations, 'blinding' concrete is used at the base of the foundation excavations and that foundation concrete is poured as soon as possible thereafter

5.10 It should be noted that should ground conditions differing significantly from those described in our report be encountered during foundation excavation, then Risk Management Limited should be contacted immediately and that the above noted allowable bearing pressure or recommended foundation type may need to be altered accordingly.

PILED FOUNDATIONS

5.11 Should piled foundations be required at this site then these would need to be bored or driven to support the foundation loads.

5.12 It is beyond our brief to provide a full and detailed pile design and the advice of a specialist piling contractor should be sought in this respect. However, the following table gives typical working loads for isolated bored piles of varying diameter to 7 metres depth.

Pile Type	Depth below existing ground level (m)	Diameter (mm)	Working Load (Tonnes)
Bored	7.00	0.30	5-10
Bored	7.00	0.45	15-20
Bored	7.00	0.65	25-30

5.13 In calculating the above working loads we have assumed a factor of safety of 2.5 on the sum of the skin friction and end bearing.

5.14 Again, it is recommended that the advice of competent piling contractors is sought as to the most suitable pile type at this site and for confirmation of the order of working load achievable given the ground conditions encountered and the proprietary pile type selected.

5.15 Settlements of such piles can be expected to be small, typically less than 5-10mm.

BASEMENT

5.16 At 3.00-3.50m depth an allowable bearing pressure of some 125 kN/m^2 could be adopted for conventional strip or pad footings, however, to keep settlements of the basement slab to within acceptable limits any uniformly distributed load on the basement slab itself should be kept to a maximum of 35-40 kN/m^2.

5.17 Note that, although groundwater was encountered at around basement founding level, once basement construction has been completed there is always a possibility that this will act as a local "sump" for surface groundwater and run-off. Therefore, we would recommend that the basement construction is "tanked" to prevent any future problems with ingress of groundwater.

SOAKAWAYS

5.18 The current falling head tests gave the following permeability (*k*) values:-

BH1 (SA1)	3.35m depth	8.10 x 10^{-6} m/sec.
BH2 (SA2)	3.50m depth	7.58 x 10^{-5} m/sec.

5.19 These results reflect "slow" to "good" drainage characteristics and suggest that conventional soakaways are likely to be successful at this site within the upper more granular deposits encountered.

BURIED CONCRETE

5.20 The results of the chemical tests at this site indicate that the soil would fall into Class DS-1 of the Building Research Establishments (BRE) classification system.

5.21 However, owing to the presence of selenite crystals within the underlying London Clay, we would recommend that sulphate resisting cement is employed in pile concrete mix design for piles into the underlying London Clay.

LAND-BORNE GAS

5.22 During the return gas/groundwater monitoring visits, no methane and a maximum carbon dioxide level of 2.3% was detected within the borehole installations.

5.23 CIRIA Publication C665 "Assessing Risks posed by Hazardous Ground gases to Buildings (Revised 2007) includes the NHBC "Traffic Light" system.

5.24 Carbon Dioxide levels were below 5% and, in addition, flow rates were below the instrument detection limit. Therefore, a gas screening value (gsv) would be low and, in accordance with the NHBC "Traffic Light" system we would consider that the current site would be classified as GREEN and, therefore, no land borne gas remedial measures would be required at this site.

SOIL SAMPLES

5.25 All soil samples will be kept for a period of 28 days after the date of the invoice for this project unless otherwise notified to Risk Management Limited in writing. Should samples be required to be stored for longer than 28 days then a storage charge may be levied.

Prepared By :	Richard Price B.Sc. Project Engineer
Checked By :	Malcolm S. Price B.Sc., M.Sc., M.I.C.E., C.Eng. Director
Distribution :	MBOK - 1 copy + pdf

The recommendations made and the opinions expressed in this report are based on the borehole records, examination of samples and the results of site and laboratory tests.

The report is issued on the condition that Risk Management Limited will under no circumstances be liable for any loss arising directly or indirectly from ground conditions between the boreholes or trial pits which have not been shown by the boreholes, trial pits or other tests carried out during the investigation.

In addition, Risk Management Limited will not be liable for any loss whatsoever arising directly or indirectly from any opinion given on the possible configuration of strata both between the borehole and/or trial pit positions and/or below the maximum depth of the investigation. Such opinions, where given, are for guidance only.

Groundwater levels may also vary with time from those reported during our site investigation due to factors such as tidal conditions, heavy pumping from nearby wells or seasonal changes.

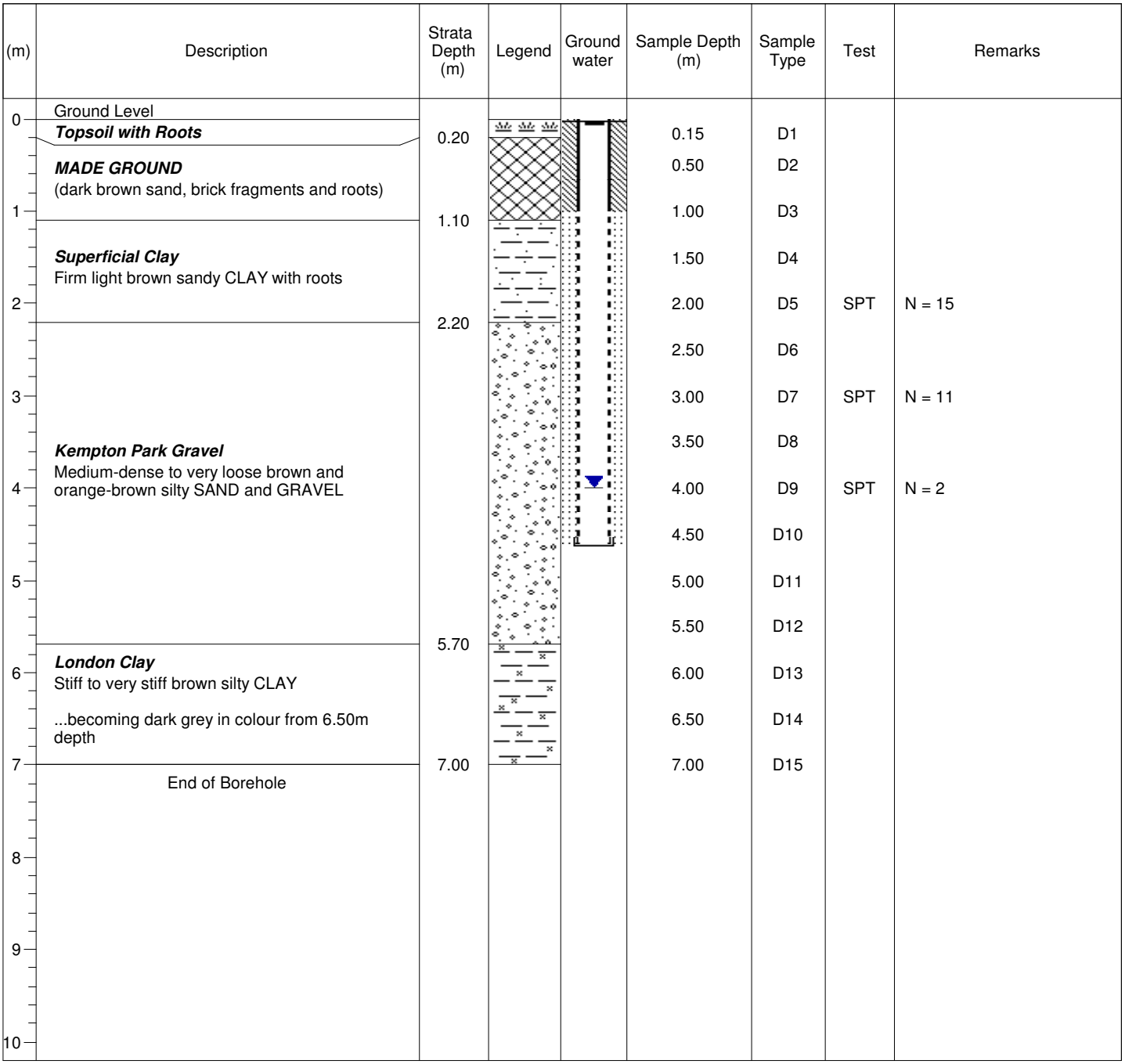
No person other than the client to whom this report is addressed, shall rely on it in any respect and no duty of care shall be owed to any such third party.

Copyright of this Report remains with Risk Management Limited and in addition we will not accept any responsibility for the report and recommendations given until our invoice is settled in full.

BOREHOLE NO. BH1

Site	: 217 Kingston Road, Teddington	**Job No.**	: RML 6259
Method	: Tracked Premier Rig	**Diameter**	: 98mm
Date	: 22nd November 2016		

Sheet 1 of 1



(m)	Description	Strata Depth (m)	Ground water	Sample Depth (m)	Sample Type	Test	Remarks
0	Ground Level						
	Topsoil with Roots	0.20		0.15	D1		
	MADE GROUND (dark brown sand, brick fragments and roots)			0.50	D2		
1		1.10		1.00	D3		
	Superficial Clay Firm light brown sandy CLAY with roots			1.50	D4		
2		2.20		2.00	D5	SPT	N = 15
				2.50	D6		
3				3.00	D7	SPT	N = 11
	Kempton Park Gravel Medium-dense to very loose brown and orange-brown silty SAND and GRAVEL			3.50	D8		
4				4.00	D9	SPT	N = 2
				4.50	D10		
5				5.00	D11		
				5.50	D12		
		5.70					
6	***London Clay*** Stiff to very stiff brown silty CLAY			6.00	D13		
	...becoming dark grey in colour from 6.50m depth			6.50	D14		
7		7.00		7.00	D15		
	End of Borehole						
8							
9							
10							

Remarks : Service pit excavated to 1.20m depth.
: Standpipe installed to 4.60m depth.
: Groundwater encountered at 4.00m depth.
:

Key: D - Disturbed sample
W - Water sample
B - Bulk sample
V - Vane Test
PP - Pocket Penetrometer
MEXE - Insitu CBR Test

RISK MANAGEMENT LIMITED
Unit 8 Paddock Barn Farm, Godstone Road, Caterham, Surrey CR3 6SF

BOREHOLE NO. BH2

Site	: 217 Kingston Road, Teddington	**Job No.**	: RML 6259
Method	: Tracked Premier Rig	**Diameter**	: 98mm
Date	: 23rd November 2016	**Sheet 1 of 1**	

(m)	Description	Strata Depth (m)	Legend	Ground water	Sample Depth (m)	Sample Type	Test	Remarks
0	Ground Level							
	MADE GROUND (Asphalt and brick fragments)	0.10			0.15	D1		
	MADE GROUND (brown silty sandy clay with brick fragments)	0.40			0.50	D2		
1	***Superficial Clay*** Firm brown silty sandy CLAY				1.00	D3		
					1.50	D4		
		1.80						
2					2.00	D5	SPT	N = 15
					2.50	D6		
3					3.00	D7	SPT	N = 12
				▼	3.50	D8		
4	***Kempton Park Gravel*** Medium-dense to very loose brown and orange-brown silty SAND and GRAVEL				4.00	D9	SPT	N = 2
					4.50	D10		
5					5.00	D11		
					5.50	D12		
6					6.00	D13		
					6.50	D14		
7					7.00	D15		
	London Clay Stiff to very stiff brown silty CLAY	7.20			7.50	D16		
8	...becoming dark grey in colour from 7.50m depth	8.00			8.00	D17		
	End of Borehole							
9								
10								

Remarks : Service pit excavated to 1.20m depth.
: Groundwater encountered at 3.50m depth.
:
:

Key: D - Disturbed sample
W - Water sample
B - Bulk sample
V - Vane Test
PP - Pocket Penetrometer
MEXE - Insitu CBR Test

RISK MANAGEMENT LIMITED
Unit 8 Paddock Barn Farm, Godstone Road, Caterham, Surrey CR3 6SF

BOREHOLE NO. BH3

Site	: 217 Kingston Road, Teddington	**Job No.**	: RML 6259
Method	: Tracked Premier Rig	**Diameter**	: 98mm
Date	: 21st November 2016		

Sheet 1 of 1

(m)	Description	Strata Depth (m)	Legend	Ground water	Sample Depth (m)	Sample Type	Test	Remarks
0	Ground Level							
	Topsoil	0.05			0.15	D1		
	MADE GROUND (dark brown silty sandy clay with brick fragments and roots)	0.40			0.50	D2		
1	***Superficial Clay*** Firm orange-brown silty sandy CLAY	1.30			1.00	D3		
					1.50	D4		
2					2.00	D5	SPT	N = 14
					2.50	D6		
3					3.00	D7	SPT	N = 12
					3.50	D8		
4					4.00	D9	SPT	N = 2
					4.50	D10		
5	***Kempton Park Gravel*** Medium-dense to very loose brown and orange-brown silty SAND and GRAVEL				5.00	D11	SPT	N = 1
					5.50	D12		
6					6.00	D13		
					6.50	D14		
7					7.00	D15		
					7.50	D16		
8					8.00	D17		
					8.50	8.50		
		8.80						
9	***London Clay*** Stiff to very stiff grey silty CLAY	9.00			9.00	9.00		
	End of Borehole							
10								

Remarks : Service pit excavated to 1.20m depth.
: Standpipe installed to 5.00m depth.
: Groundwater encountered at 3.60m depth.
:

Key: D - Disturbed sample
W - Water sample
B - Bulk sample
V - Vane Test
PP - Pocket Penetrometer
MEXE - Insitu CBR Test

RISK MANAGEMENT LIMITED
Unit 8 Paddock Barn Farm, Godstone Road, Caterham, Surrey CR3 6SF

Standard Penetration Test (SPT) versus Depth Profile

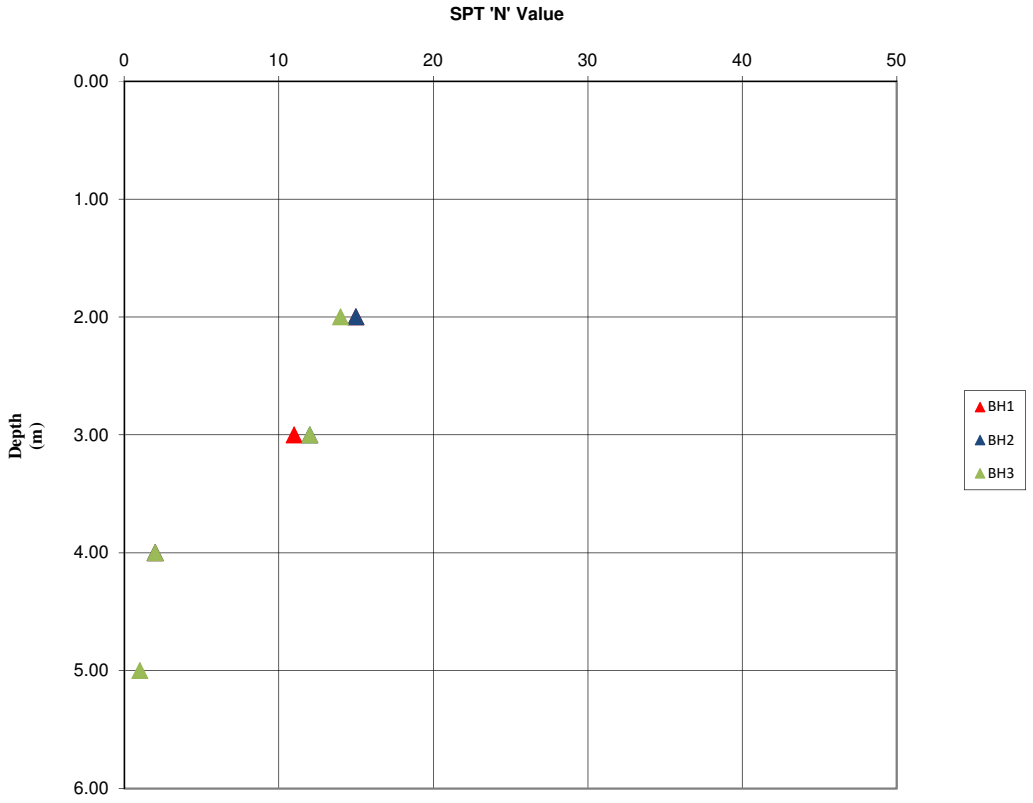
Risk Management Limited
Tel : 01883 343572
Fax : 01883 344060

Project Name : 217 Kingston Road, Teddington, TW11 9JN

Job No. : RML 6259

Date : December 2016

BH1		BH2		BH3	
Depth (m)	SPT 'N' value	Depth (m)	SPT 'N' value	Depth (m)	SPT 'N' value
2.00	15	2.00	15	2.00	14
3.00	11	3.00	12	3.00	12
4.00	2	4.00	2	4.00	2
				5.00	1



FALLING HEAD PERMEABILITY TEST

Risk Management Limited
Tel : 01883 343572
Fax : 01883 344060

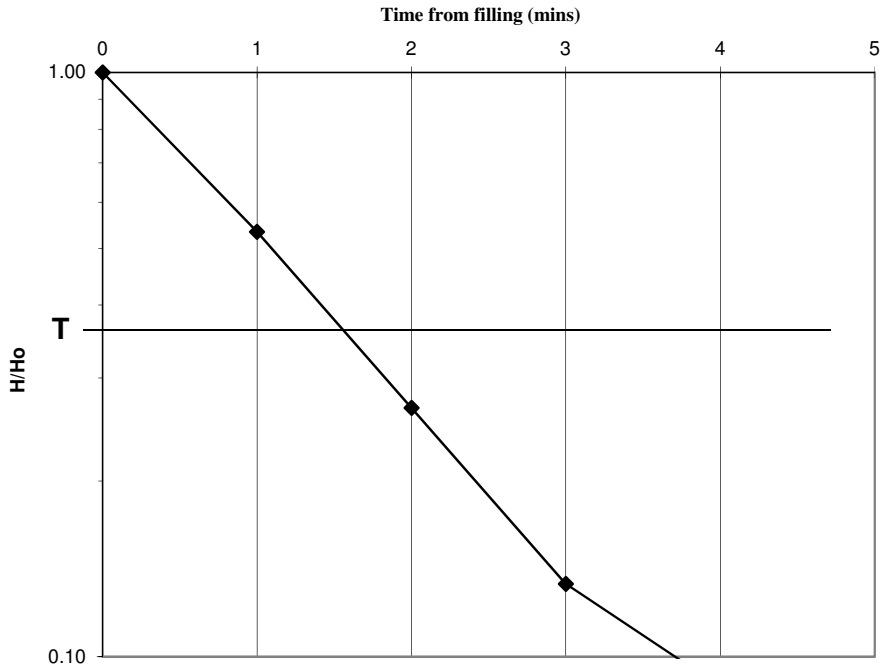
Project Name : 217 Kingston Road, Teddington, TW11 9JN

SOAKAWAY TEST SA1 (BH1)

Job No. RML 6259
Date : December 2016

Test Depth	H_0 =				
3.35	2.25				
Depth (m)	**Time (mins)**	**H**	**H/H_0**		
1.100	0	2.25	1.00		
2.150	1	1.20	0.53		
2.750	2	0.60	0.27		
3.050	3	0.30	0.13		
3.150	4	0.20	0.09		
3.200	5	0.15	0.07		

Diameter of pipe =	0.054	(m)
Area (A) =	0.0023	(m^2)
Intake factor (F) =	3.14	
Basic Time Factor (T) =	1.5	(min)
Permeability (k) =	**8.10E-06**	m/sec



FALLING HEAD PERMEABILITY TEST

Risk Management Limited
Tel : 01883 343572
Fax : 01883 344060

Project Name : 217 Kingston Road, Teddington, TW11 9JN

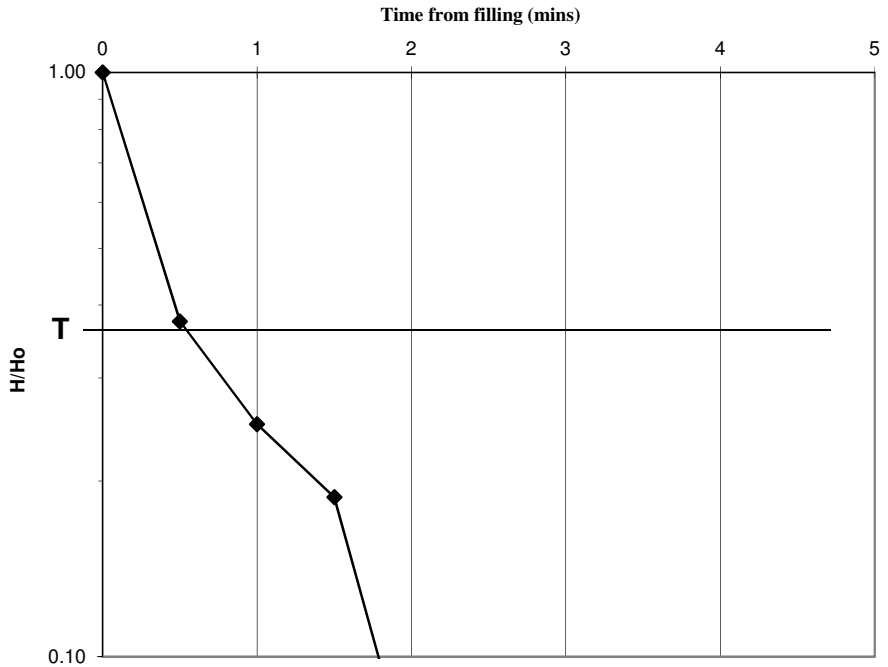
SOAKAWAY TEST SA2 (BH2)

Job No. RML 6259
Date : December 2016

Test Depth	H_0 =
3.5	0.40

Depth (m)	Time (mins)	H	H/H_0
3.100	0	0.40	1.00
3.350	0.5	0.15	0.38
3.400	1	0.10	0.25
3.425	1.5	0.08	0.19
3.475	2	0.02	0.06
3.500	2.5	0.00	0.00

Diameter of pipe =	0.054	(m)
Area (A) =	0.0023	(m^2)
Intake factor (F) =	1.01	
Basic Time Factor (T) =	0.5	(min)
Permeability (k) =	**7.58E-05**	m/sec

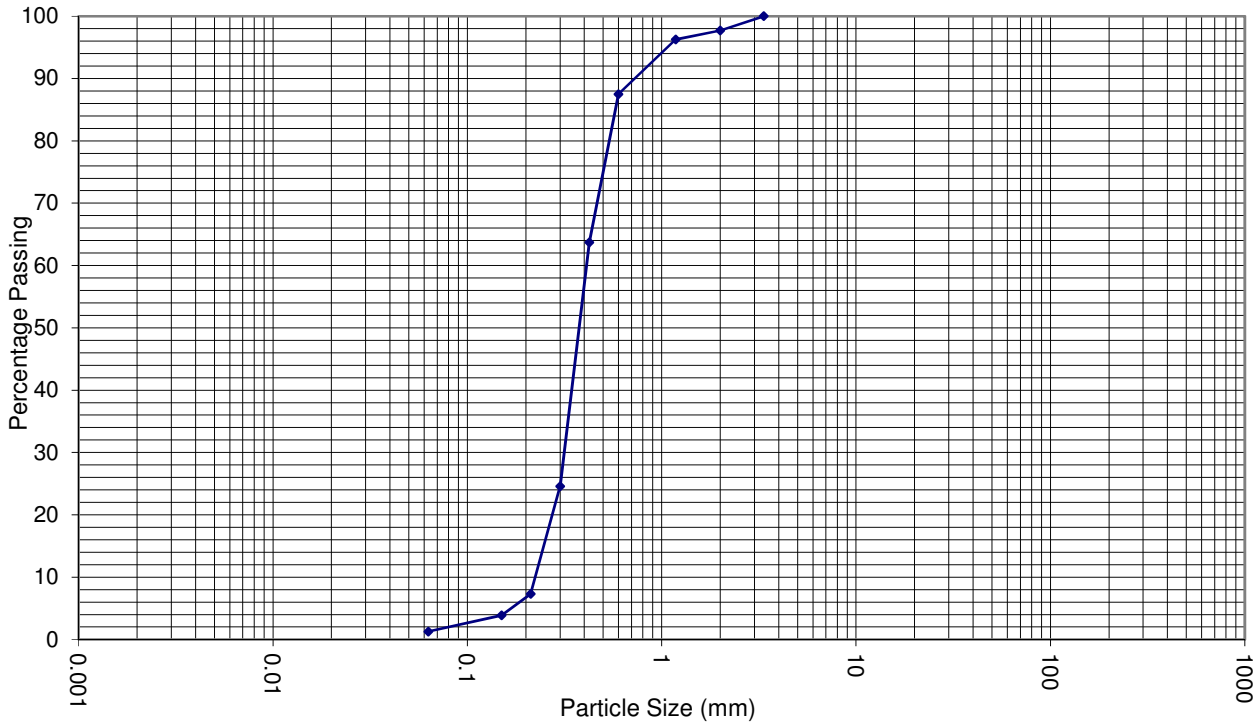


Results of Particle Size Distribution Tests

Project Name :	**217 Kingston Road, Teddington TW11 9JN**			**Project No.**	**RML 6259**
Borehole No.	**BH1**	**Sample No.**	**D8**	**Depth (m)**	**3.50m**

Test Method : BS 1377 : Part 2 : 1990 : Clause 9

Sieve (mm)	Passing (%)	Sieve (mm)	Passing (%)
200	100	2	98
125	100	1.18	96
90	100	0.6	87
75	100	0.425	64
63	100	0.3	25
50	100	0.212	7
37.5	100	0.15	4
28	100	0.063	1
20	100	Pipette	
14	100	Particle Size	% Passing
10	100		
6.3	100		
5	100		
3.35	100		



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	COBBLES	BOULDERS
	SILT			SAND			GRAVEL				

Description :

Brown and orange-brown silty SAND .

PROJECT NAME : 217 Kingston Road, Teddington, TW11 9JN

PROJECT NO: RML 6259

Date	December 2016
Page	1 of 1

Sample Details				Classification Tests					Density Tests		Undrained Triaxial Compression Tests			Chemical Results				
BH No.	Depth (m)	Sample No.	Description	MC (%)	LL (%)	PL (%)	PI	<425 mic (%)	Bulk (Mg/m^3)	Dry (Mg/m^3)	Cell Pressure kPa	Deviator Stress kPa	Mean Shear Stress kPa	pH	W/S SO_4 (g/l)	Total SO_4 (%)	Water SO_4 (g/l)	Other tests and comments
BH1	1.50	D4	Light brown sandy CLAY with roots	5	23	11	12	>95										Class CL
	2.00	D5												4.8	0.20			
	6.50	D13	Very stiff dark grey silty CLAY	25	59	24	35	100	1.99	1.59	130	340	170					Class CH
	7.00	D15	Very stiff dark grey silty CLAY	25					2.03	1.62	140	378	189					
BH2	2.00	D5												6.6	<0.02			
BH2	8.00	D17	Very stiff dark grey silty CLAY	23					2.07	1.68	160	380	190					
BH3	2.00	D5												7.6	0.03			
BH3	9.00	D19	Very stiff dark grey silty CLAY	25					2.02	1.61	180	445	223					

SUMMARY OF GEOTECHNICAL TESTING

Risk Management

Undrained Shear Strength versus Depth Profile

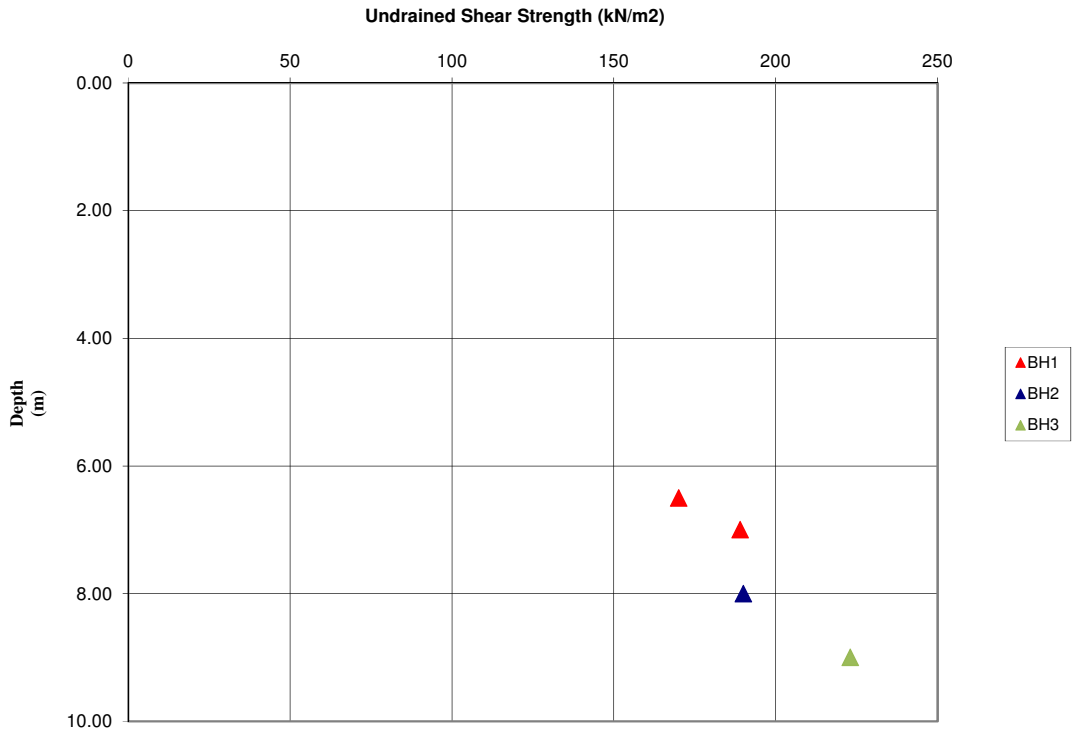
Risk Management Limited
Tel : 01883 343572
Fax : 01883 344060

Project Name : 217 Kingston Road, Teddington, TW11 9JN

Job No. : RML 6259

Date : December 2016

BH1		BH2		BH3	
Depth (m)	Shear Strength (kN/m^2)	Depth (m)	Shear Strength (kN/m^2)	Depth (m)	Shear Strength (kN/m^2)
6.50	170	8.00	190	9.00	223
7.00	189				



Risk Management Limited
Tel : 01883 343572

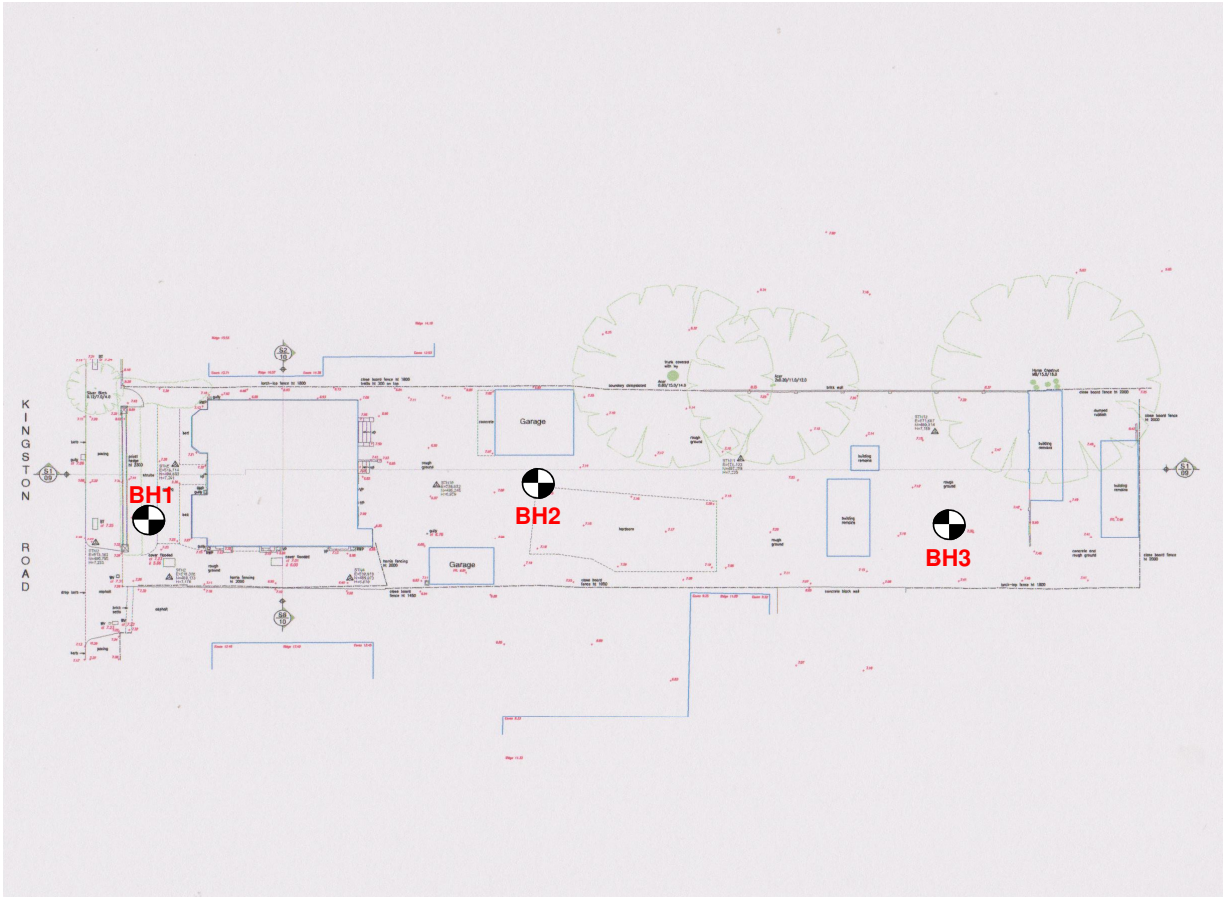
GROUNDWATER & GAS MONITORING RESULTS

Project Name:	217 Kingston Road, Teddington, TW11 9JN	Project No. :	RML 6259
		Date :	December 2016

BH No.	Date	Pressure (mb)	Oxygen (%)	Carbon Dioxide (%)	Methane (%)	Methane LEL (%)	Flow Rate (l/hr)	Groundwater Level (m)
BH1	28/11/16	1001	20.0	0.0	0.0	0.0	0	3.90
	06/12/16	1020	18.2	1.8	0.0	0.0	0	3.50
	12/12/16	997	17.7	2.3	0.0	0.0	0	3.35
BH3	28/11/16	1001	19.9	0.1	0.0	0.0	0	3.60
	06/12/16	1020	19.4	0.6	0.0	0.0	0	3.60
	12/12/16	998	19.1	0.9	0.0	0.0	0	3.50

KEY

Borehole Location



Risk Management

Title : **SKETCH FIELDWORK LOCATION PLAN**

RISK MANAGEMENT LIMITED

Tel : 01883 343572
Fax : 01883 344060

Project Location : 217 Kingston Road, Teddington, TW11 9JN

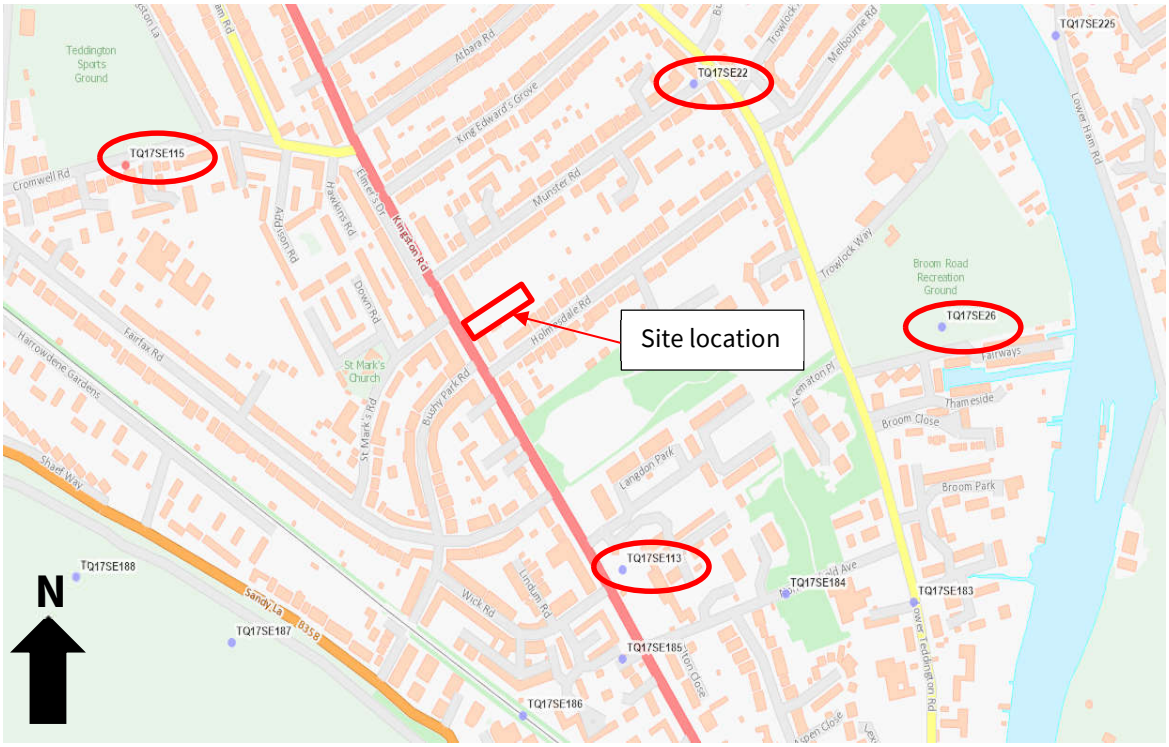
Report Date : December 2016

Scale : NTS

Drawn By : MSP

Drg. No. RML 6259 /1

Appendix C – BGS Historical Borehole Logs



Borehole reviewed to create preliminary ground model

Client	Project	Job No
Midco Holdings Limited	**217 Kingston Road**	**L1338-GEO-R001**
BYRNELOOBY	Title **BGS Borehole Records**	**Appendix C**

British Geological Survey

Version 2.0.6.4

BGS ID: 581409 : BGS Reference: TQ17SE22
British National Grid (27700) : 517300,170800
Report an issue with this borehole

<< < Prev Page 1 of 2 Next > >>

21 Pages 21-22

TQ 17SE/22

Mid' sarg 6" 25 NE/E.

Δ 173 708

GROUND EXPLORATIONS LIMITED

BOREHOLE SECTION SHEET

Date July, 1954

CONTRACT NAME Broom Road. ORDER NO.

Bored for : Borough Engineer & Surveyor, Borough of Twickenham.

Address : Municipal Offices, Twickenham.

Address of Site : Broom Road,

District or Town : Teddington. County : Middx.

Standing Water Level : Below Surface : Dia. of Borehole : 5 Inches.

Water Struck (1) None (2) (3)

Boring Commenced : 29.6.54. Boring Completed : 29.6.54.

Special Remarks : Boring from staging in river. Read the Instructions

Jar Samples : 6522-6'6"; 6523-11'6"; 6524-13'6"; 6525-15'6";

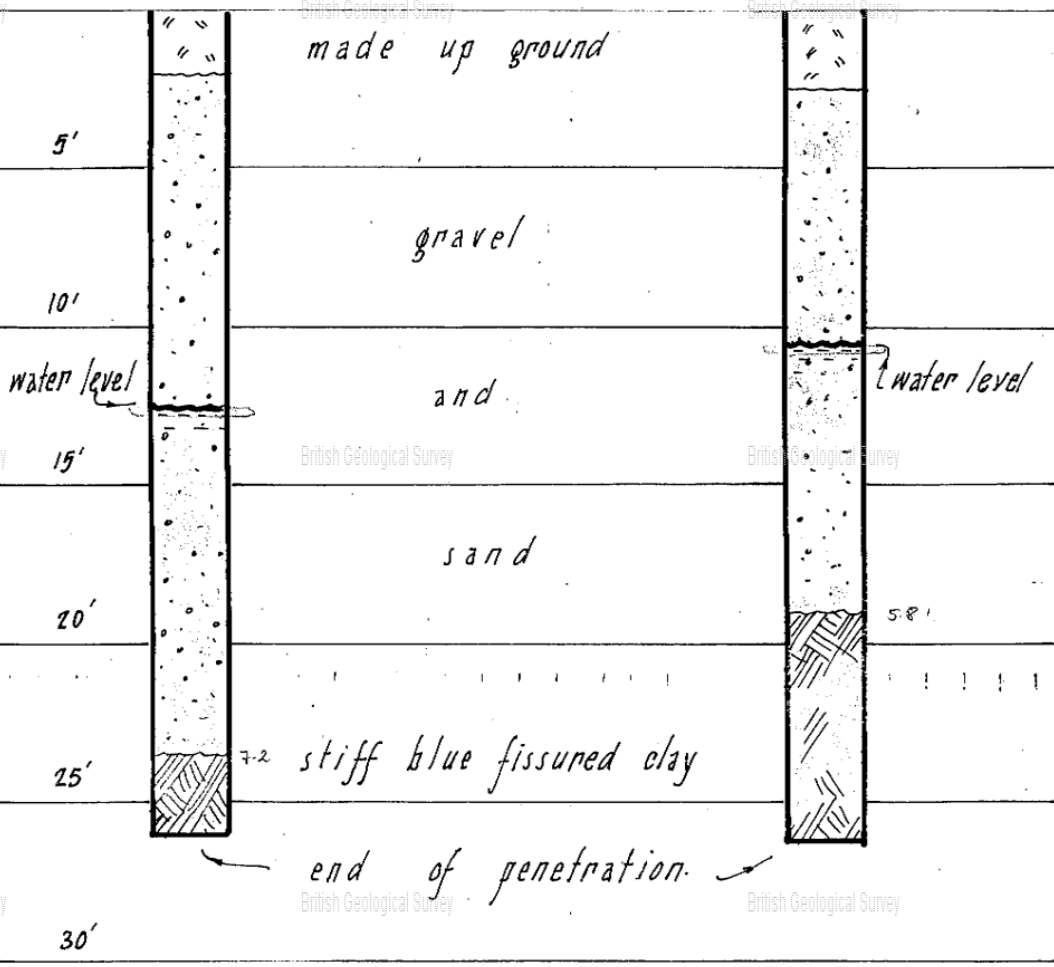
Core Samples :

DESCRIPTION OF STRATA	Thickness Feet	Thickness Inches	Depth Below Surface Feet	Depth Below Surface Inches
The descriptions are given in accordance with the Civil Engineering Code of Practice No. 1 "Site Investigations." No responsibility is accepted for these descriptions and clients should examine the samples submitted.				
No. 1 Boring				
Soft Clayey Sand	3	0	3	0
Sand and Gravel	9	6	12	6

TQ 17 SE / 26

A 176 705

1.



BOREHOLE DATA from report dated May 1960.

SITE : BROOM ROAD. TEDDINGTON

Middlesex County Council
ARCHITECT'S DEPARTMENT
H.J. Whitfield Lewis F.R.I.B.A. County Architect
1 Queen Anne's Gate Buildings, Dartmouth Street, Westminster, London SW1 TRAfalgar 7799x 285
(Structural Section)

drawn/checked 7/62. A.
first issue
printed

SCALE
job
drawing

sheet size A4
297 x 210 mm

TQ17SE/113 Δ Site NGR 172 702

TQ17/65

WELL BORING at Hampton Wick County Middlesex

Geol. map 1 in. map New Series 270 6 in. map

Made by C Isler & Co Date 1924

Sunk feet. Bored 20. feet.

Communicated by C Isler & Co

Height above Ordnance Datum Rest level of water 8'

Yield about 800 g.p.h.

Quality (with copy of analysis on separate sheet)

54

GEOLOGICAL FORMATION.	NATURE OF STRATA.	THICKNESS. Feet.	Inches.	DEPTH. Feet.	Inches.
	Clinkers	—	6		
	Made ground	1	6	2	—
	Loamy sands	3	—	5	—
	Ballast	15	—	20	—
	Lined 19 ft of 6" tubes.				
	Hampton Court Gas Co Hampton Wick				
O.D. 29 ft. Site see Survey VI. S.E.	Information from the gas Co., 14. 5. 40: Two wells [(a) & (b) sited on 6 in Survey VI S.E] — also a third used only as a sump. Rest level formerly about 8 ft. down, recently 5 ft. down. These are dug wells, original 1 ster small borings being unsatisfactory, through silting up. S.C.A.H. Now sited on 6" Middlesex 2 S.N.E.E.				

GEOLOGICAL SURVEY AND MUSEUM
JERMYN STREET, LONDON S.W. 1.

(B10619). Wt. 15824—S123. 2500. 11/25. Gp. 160. O.A.

scans.bgs.ac.uk/sobi_scans/boreholes/581550/images/12200604.html 2/2

NGR 1650 7070 TQ 17 /67
TQ17SE/115

BOREHOLE SECTION SHEET

TQ 17/67

LE GRAND, SUTCLIFF & GELL LTD.

Date ..... 19.....

CONTRACT NAME 75" MAIN. ORDER No. 2756.

Bored for : METROPOLITAN WATER BOARD,

Address :

Address of Site : NEW RIVER HEAD, ROSEBERY AVENUE, E.C.

District or Town : OPPOSITE ST. MARY'S R.C., CHURCH ROAD, County : MIDDLESEX.

Standing Water Level : TEDDINGTON Ft. Ins. Below Surface Pumping W.L. Ft. Ins. Below Surface

Dia. of Borehole : NIL Inches Yield of Water : G.P.H. O.D. of Site : 29.79

Particulars of Tubing Inserted : 10 OD + 9.08.

Water Struck (1) Ft. B.S. (2) Ft. B.S. (3) Ft. B.S. (4) Ft. B.S.

Boring Commenced : Nil Boring Completed : Ref. T.S.B./S.B.

Special Remarks : 20.3.52. 26.3.52

DESCRIPTION OF STRATA	THICKNESS FEET	THICKNESS INCHES	DEPTH BELOW SURFACE FEET	DEPTH BELOW SURFACE INCHES
Clients are requested to examine the samples of the strata submitted, as the descriptions employed below are general terms and responsibility is not accepted for their application to commercial purposes				
No. 52 Boring				
Made Up Ground.	2	6	2	6
Sandy Clay and Stones.	7	6	10	-
Gravel.	7	6	17	6
Gravel & Brown Clay.	1	-	18	6
Gravel.	3	6	22	-
Brown Clay.	3	-	25	-
Blue Clay.	52	-	77	-
Clay Stone.	1	-	78	-
Blue Clay.	62	-	140	-

Dirt

R.B.

K.P.

12.37.

4½" Undisturbed Core Samples taken at 110', 125' and 140' b.s.

LEGRAND, SUTCLIFF & GELL LTD.

Site transferred to 1"240 and 6" 25 NE/E Middlesex. SMA 11.7.52.

Rec. 4.7.52. Total from Surface : 140 - 140 -

Appendix D – Drainage Strategy Drawings

A1

GENERAL NOTES

LEGEND

IMPERMEABLE AREA (DRAINED TO NETWORK) (397M²)

IMPERMEABLE AREA (DRAINED TO GROUND) (163M²)

PERMEABLE AREA (GRASS) (518M²)

TOTAL AREA = 1,078M²

KINGSTON ROAD

S2 10

S1 09

S8 10

THIS AREA HAS FORMAL DRAINAGE INFRASTRUCTURE THAT DISCHARGES TO THE LOCAL DRAINAGE NETWORK

SEVERAL IMPERMEABLE SURFACES IN THIS AREA DISCHARGING TO ADJACENT PERMEABLE AREA (GRASS)

SEVERAL IMPERMEABLE SURFACES IN THIS AREA DISCHARGING TO ADJACENT PERMEABLE AREA (GRASS)

Silver Birch 0.12/7.0/4.0

trunk covered with ivy

Acer 0.80/15.0/14.0

Acer 2x0.20/11.0/12.0

Horse Chestnut MB/15.0/16.0

boundary delapidated

brick wall

larch-lap fence ht 1800

close board fence ht 1800 trellis ht 300 on top

close board fence ht 2000

Garage

Garage ht 4.40

Garage ht 4.40

Ridge 15.53

Ridge 14.18

Eaves 12.53

Eaves 13.71

Ridge 16.57

Eaves 14.38

Eaves 12.45

Ridge 17.40

Eaves 12.45

Eaves 9.25

Ridge 11.20

Eaves 9.33

Eaves 9.33

Ridge 11.33

kerb

paving

gully cl 7.06

BT cl 7.25

BT cl 7.24

WV cl 7.31

drop kerb

asphalt

brick setts

WV cl 7.22

WV cl 7.23

kerb

paving

asphalt

close board fence ht 1450

concrete block wall

close board fence ht 1800

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Rev	Date	Description	By	Chk	App

BYRNELOOBY

WWW.BYRNELOOBY.COM

IRELAND | UK | UAE | BAHRAIN | KSA

CLIENT

a
b
c

PROJECT

217 KINGSTON ROAD, TEDDINGTON

DRAWING TITLE

PRE-DEVELOPMENT SITE LAYOUT PERMEABILITY ASSESSMENT AND DRAINAGE STRATEGY

STATUS

PLANNING

Date: MAR '22	Scale: 1:100	Drawn: AM	Chk: AM	App: CG
Project No: ???	Drg. No: 001			Rev: ???

A1

GENERAL NOTES

LEGEND

- IMPERMEABLE AREA (DRAINED TO NETWORK) (386M²)
- IMPERMEABLE AREA (DRAINED TO SOAKAWAY) (249M²)
- PERMEABLE AREA (GRASS) (325M²)
- GREEN ROOF (118M²)

TOTAL AREA = 1,078M²

CATCHMENT 1

- IMPERMEABLE AREA (DRAINED TO NETWORK) (386M²)
- IMPERMEABLE AREA (DRAINED TO SOAWAWAY) (0M²)
- PERMEABLE AREA (GRASS) (0M²)
- GREEN ROOF (0M²)

TOTAL AREA = 386M²

CATCHMENT 2

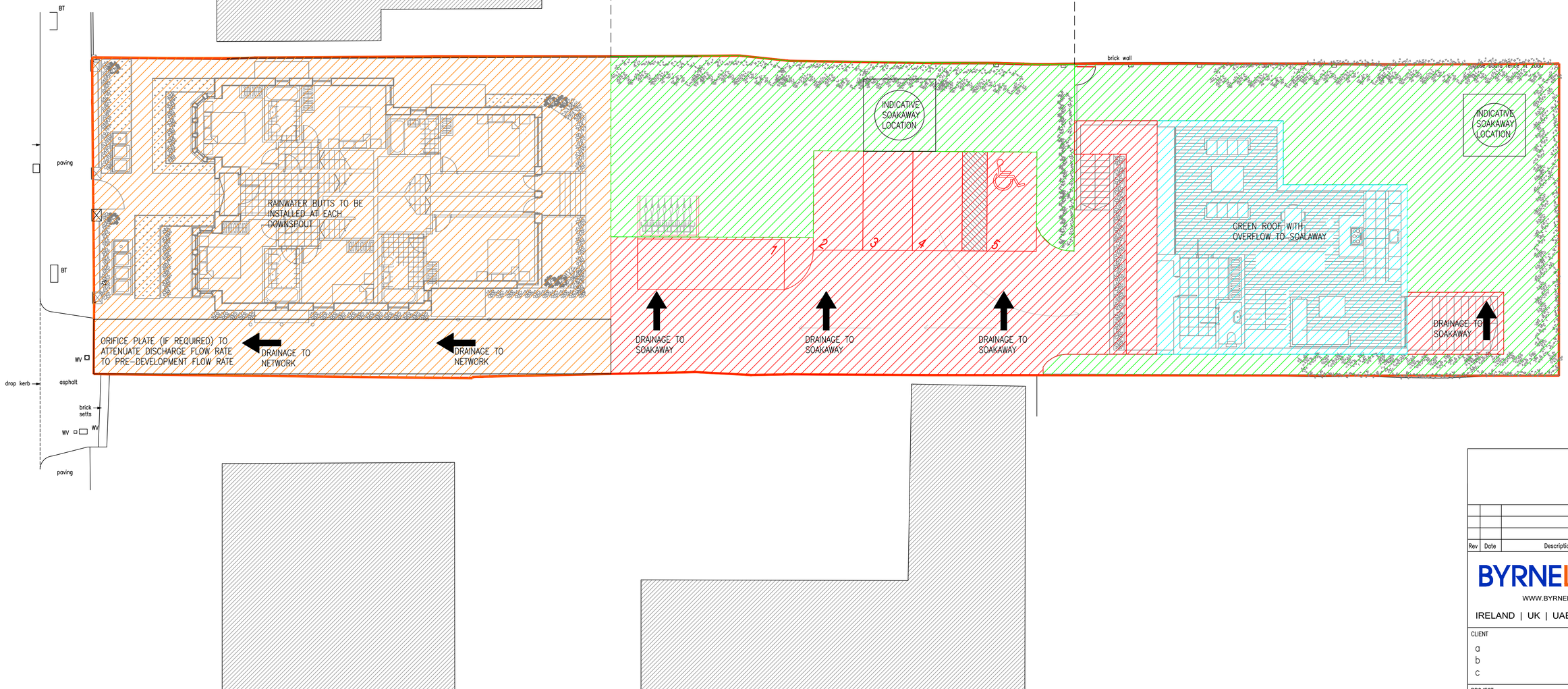
- IMPERMEABLE AREA (DRAINED TO NETWORK) (0M²)
- IMPERMEABLE AREA (DRAINED TO SOAWAWAY) (215M²)
- PERMEABLE AREA (GRASS) (149M²)
- GREEN ROOF (0M²)

TOTAL AREA = 364M²

CATCHMENT 3

- IMPERMEABLE AREA (DRAINED TO NETWORK) (0M²)
- IMPERMEABLE AREA (DRAINED TO SOAWAWAY) (34M²)
- PERMEABLE AREA (GRASS) (176M²)
- GREEN ROOF (118M²)

TOTAL AREA = 328M²



Rev	Date	Description	By	Chk	App

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IRELAND | UK | UAE | BAHRAIN | KSA

CLIENT

a
b
c

PROJECT

217 KINGSTON ROAD, TEDDINGTON

DRAWING TITLE

POST-DEVELOPMENT SITELAYOUT PERMEABILITY ASSESSMENT AND DRAINAGE STRATEGY

STATUS

PLANNING

Date: MAR '22	Scale: 1:100	Drawn: AM	Chk: AM	App: CG
Project No: ???	Drg. No: 002			Rev: ???

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Appendix E – UK SuDS Calculations

Surface water storage requirements for sites

www.uksuds.com | Storage estimation tool

Calculated by:	Aidan McCarthy
Site name:	217 Kingston Road,
Site location:	Teddinton London

This is an estimation of the storage volume requirements that are needed to meet normal best practice criteria in line with Environment Agency guidance "Rainfall runoff management for developments", SC030219 (2013), the SuDS Manual C753 (Ciria, 2015) and the non-statutory standards for SuDS (Defra, 2015). It is not to be used for detailed design of drainage systems. It is recommended that hydraulic modelling software is used to calculate volume requirements and design details before finalising the design of the drainage scheme.

Site Details

Latitude:	51.42137° N
Longitude:	0.31876° W
Reference:	3813337317
Date:	Mar 10 2022 17:10

Site characteristics

Total site area (ha):	0.0386
Significant public open space (ha):	0
Area positively drained (ha):	0.0386
Impermeable area (ha):	0.0386
Percentage of drained area that is impermeable (%):	100
Impervious area drained via infiltration (ha):	0
Return period for infiltration system design (year):	10
Impervious area drained to rainwater harvesting (ha):	0
Return period for rainwater harvesting system (year):	10
Compliance factor for rainwater harvesting system (%):	66
Net site area for storage volume design (ha):	0.04
Net impermable area for storage volume design (ha):	0.04
Pervious area contribution to runoff (%):	30

* where rainwater harvesting or infiltration has been used for managing surface water runoff such that the effective impermeable area is less than 50% of the 'area positively drained', the 'net site area' and the estimates of Q_{BAR} and other flow rates will have been reduced accordingly.

Design criteria

Climate change allowance factor:	1.4
Urban creep allowance factor:	1.1
Volume control approach	Use long term storage
Interception rainfall depth (mm):	5
Minimum flow rate (l/s):	2

Methodology

esti	IH124
Q_{BAR} estimation method:	Calculate from SPR and SAAR
SPR estimation method:	Calculate from SOIL type

Soil characteristics

	Default	Edited
SOIL type:	2	2
SPR:	0.3	0.3

Hydrological characteristics

	Default	Edited
Rainfall 100 yrs 6 hrs:	--	63
Rainfall 100 yrs 12 hrs:	--	98.56
FEH / FSR conversion factor:	1.28	1.28
SAAR (mm):	600	600
M5-60 Rainfall Depth (mm):	20	20
'r' Ratio M5-60/M5-2 day:	0.4	0.4
Hydological region:	6	6
Growth curve factor 1 year:	0.85	0.85
Growth curve factor 10 year:	1.62	1.62
Growth curve factor 30 year:	2.3	2.3
Growth curve factor 100 years:	3.19	3.19
Q_{BAR} for total site area (l/s):	0.06	0.06
Q_{BAR} for net site area (l/s):	0.06	0.06

Site discharge rates	Default	Edited	Estimated storage volumes	Default	Edited
1 in 1 year (l/s):	2	2	Attenuation storage 1/100 years (m^3):	13	13
1 in 30 years (l/s):	2	2	Long term storage 1/100 years (m^3):	0	0
1 in 100 year (l/s):	2	2	Total storage 1/100 years (m^3):	13	13

This report was produced using the storage estimation tool developed by HRWallingford and available at www.uksuds.com. The use of this tool is subject to the UK SuDS terms and conditions and licence agreement, which can both be found at http://uksuds.com/terms-and-conditions.htm. The outputs from this tool have been used to estimate storage volume requirements. The use of these results is the responsibility of the users of this tool. No liability will be accepted by HR Wallingford, the Environment Agency, CEH, Hydrosolutions or any other organisation for the use of these data in the design or operational characteristics of any drainage scheme.

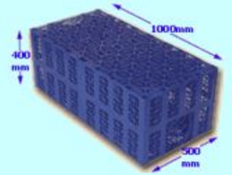
HR Wallingford
Working with water

Infiltration system design

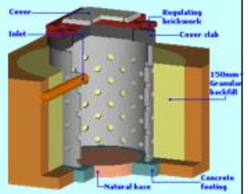
INTRODUCTION | LIABILITY

Soakaways

Rectangular Soakaway design



Ring Soakaway design



Infiltration trenches

Infiltration Trench design

Software licence
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Visit our website at www.uksuds.com/terms-and-conditions for the full terms to use this tool

HOME | CompareOptions | About HR Wallingford

Ring Soakaway

Parameters | Area to be drained | Design rainfall event | Results

Geometry

Width (m)	3.5	Length (m)	3.5
Diameter (m)	2.4	Soakaway base area (m2)	12.25

Porosity	0.4	Infiltration coefficient (m/s)	0.0000758
Area to be drained (m2)	215	Factor of safety	3

Rainfall intensity factors

M5-60	20	Rainfall ratio r	0.45 Change
Climate change factor	1.1	FEH factor	1.0
Return Period (years)	10 Change		

Results

Soakaway Minimum Height (m) (Maximum water depth) **0.600**

Time for Half-emptying (h) **1.6**

To save the results of your calculations, click on the "Compare" buton first, and then click on the "Save as" button (See "i" button for more information)

Update | Close | Compare | Save As | < Back

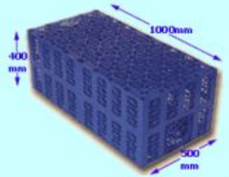
HR Wallingford
Working with water

Infiltration system design

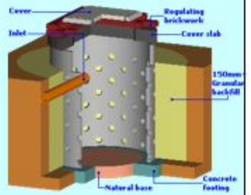
INTRODUCTION | LIABILITY

Soakaways

Rectangular Soakaway design



Ring Soakaway design



Infiltration trenches

Infiltration Trench design

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Ring Soakaway

Parameters | Area to be drained | Design rainfall event | Results

Geometry

Width (m)	3	Length (m)	3
Diameter (m)	2.1	Soakaway base area (m2)	9

Porosity	0.4	Infiltration coefficient (m/s)	0.0000758
Area to be drained (m2)	152	Factor of safety	3

Rainfall intensity factors

M5-60	20	Rainfall ratio r	0.45 Change
Climate change factor	1.1	FEH factor	1.0
Return Period (years)	10 Change		

Results

Soakaway Minimum Height (m) (Maximum water depth)	0.560	Time for Half-emptying (h)	1.49

To save the results of your calculations, click on the "Compare" buton first, and then click on the "Save as" button (See "i" button for more information)

Update | Close | Compare | Save As | < Back

HOME | CompareOptions | About HR Wallingford

Appendix F – PDisp and XDisp Output

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File XDisp Long Term.xdd
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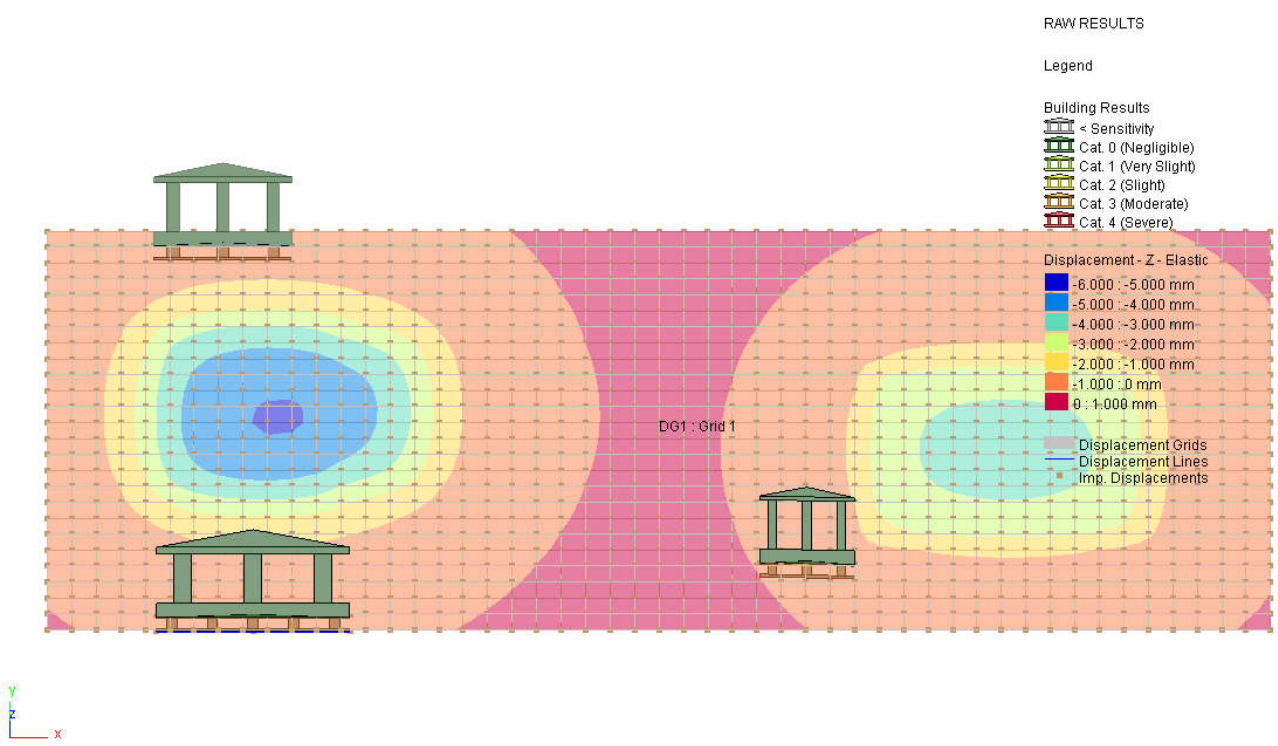
Specific Building Damage Results - Critical Segments within Each Building

START_TABLE

Stage: Ref.	Stage: Name	Specific Building: Ref.	Specific Building: Name	Parameter	Critical Sub-Building	Critical Segment	Start [m]	End [m]	Min Radius of Curvature (Hogging) [mm]	Max Slope [%]	Max Settlement [m]	Max Tensile Strain	Min Radius of Curvature (Sagging) [m]	Damage Category
0	Base Model	0	215 KR	All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
		0	219A KR	All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
				All vertical displacements are less than the limit sensitivity.										
		0	219B KR	Max Slope	GL	1	2.7607	5.5000	None	73.497E-6	0.41567	409.81E-6	-	0 (Negligible)
				Max Settlement	GL	1	2.7607	5.5000	None	73.497E-6	0.41567	409.81E-6	-	0 (Negligible)
				Max Tensile Strain	GL	1	2.7607	5.5000	None	73.497E-6	0.41567	409.81E-6	-	0 (Negligible)
				Min Radius of Curvature (Hogging)	-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)	-	-	-	-	-	-	-	-	-	-
		0	215 KRB	All vertical displacements are less than the										

```
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                0       219A KRB        All vertical displacements are less than
the limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                                All vertical displacements are less than the
limit sensitivity.
                0       219B KRB        Max Slope       BL      1       2.7607
5.5000  None    75.774E-6       0.42215 0.0020618       -       -       0
(Negligible)
                                Max Settlement  BL      1       2.7607  5.5000
None    75.774E-6       0.42215 0.0020618       -       -       0 (Negligible)
                                Max Tensile Strain      BL      1       2.7607
5.5000  None    75.774E-6       0.42215 0.0020618       -       -       0
(Negligible)
                                Min Radius of Curvature (Hogging)
-       -       -       -       -       -       -       -       -       -
                                Min Radius of Curvature (Sagging)
-       -       -       -       -       -       -       -       -       -
END_TABLE
```


RAW RESULTS
Legend
Building Results
< Sensitivity
Cat. 0 (Negligible)
Cat. 1 (Very Slight)
Cat. 2 (Slight)
Cat. 3 (Moderate)
Cat. 4 (Severe)
Displacement - Z - Elastic
-6.000 : -5.000 mm
-5.000 : -4.000 mm
-4.000 : -3.000 mm
-3.000 : -2.000 mm
-2.000 : -1.000 mm
-1.000 : 0 mm
0 : 1.000 mm
Displacement Grids
Displacement Lines
Imp. Displacements
DG1 : Grid 1
Y
Z
X

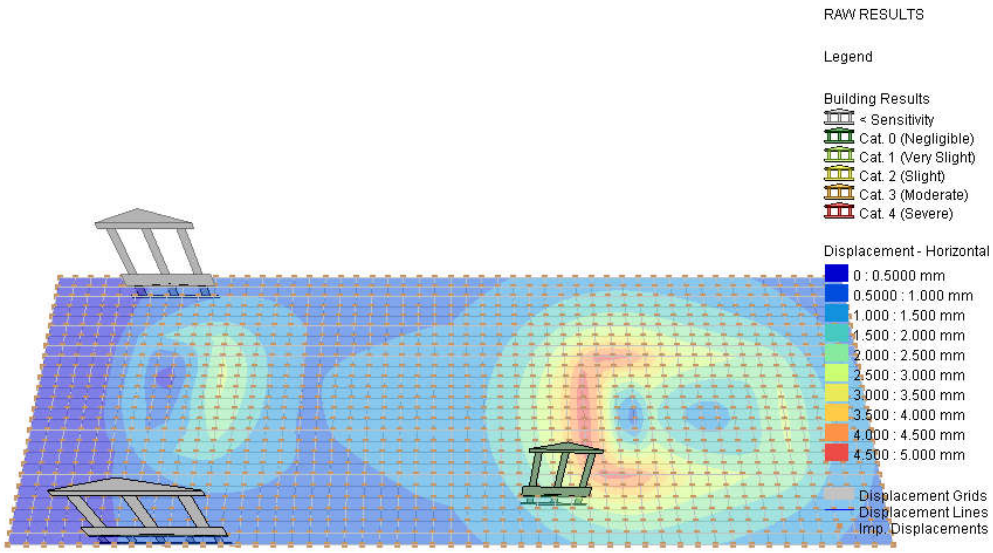
Specific Building Damage Results - Critical Segments within Each Building

Stage: Ref.	Stage: Name	Specific Building: Ref.	Specific Building: Name	Parameter	Critical Sub-Building	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
0	Base Model	0	215 KR	Max Slope	GL	1	0.0	7.9900	None	**37.487E-6**	0.44596	0.034522	-	-	0 (Negligible)
				Max Settlement	GL	1	0.0	7.9900	None	37.487E-6	**0.44596**	0.034522	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	0.0	7.9900	None	37.487E-6	0.44596	**0.034522**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-
		0	219A KR	Max Slope	GL	1	0.0	11.200	None	**12.664E-6**	0.17308	0.025185	-	-	0 (Negligible)
				Max Settlement	GL	1	0.0	11.200	None	12.664E-6	**0.17308**	0.025185	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	0.0	11.200	None	12.664E-6	0.17308	**0.025185**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-
		0	219B KR	Max Slope	GL	1	2.7607	5.5000	None	**85.076E-6**	0.37083	0.0026481	-	-	0 (Negligible)
				Max Settlement	GL	1	2.7607	5.5000	None	85.076E-6	**0.37083**	0.0026481	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	2.7607	5.5000	None	85.076E-6	0.37083	**0.0026481**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-
		0	215 KRB	Max Slope	BL	1	0.0	7.9900	None	**36.551E-6**	0.42789	0.011996	-	-	0 (Negligible)
				Max Settlement	BL	1	0.0	7.9900	None	36.551E-6	**0.42789**	0.011996	-	-	0 (Negligible)
				Max Tensile Strain	BL	1	0.0	7.9900	None	36.551E-6	0.42789	**0.011996**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-
		0	219A KRB	Max Slope	BL	1	5.6200	11.200	None	**12.202E-6**	0.16165	0.0084417	-	-	0 (Negligible)
				Max Settlement	BL	1	5.6200	11.200	None	12.202E-6	**0.16165**	0.0084417	-	-	0 (Negligible)
				Max Tensile Strain	BL	1	5.6200	11.200	None	12.202E-6	0.16165	**0.0084417**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-
		0	219B KRB	Max Slope	BL	1	2.7607	5.5000	None	**86.120E-6**	0.36902	0.0012470	-	-	0 (Negligible)
				Max Settlement	BL	1	2.7607	5.5000	None	86.120E-6	**0.36902**	0.0012470	-	-	0 (Negligible)
				Max Tensile Strain	BL	1	2.7607	5.5000	None	86.120E-6	0.36902	**0.0012470**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-

Displacement Results - Displacement Lines

Stage: Ref.	Stage: Name	Disp. Line: Ref.	Disp. Line: Name	Chainage [m]	x [m]	y [m]	z [m]	δx [mm]	δy [mm]	δz [mm]	δH// [mm]	δHperp. [mm]	Angle [°]	
0	Base Model	1	215 Line 1	0.0	6.20000	19.38000	7.20000	-3.1284	4.3168	-0.27330	-3.1284	4.3168	0.0	*
				4.0000	10.20000	19.38000	7.20000	-1.9871	5.4828	-0.42329	-1.9871	5.4828	0.0	*
				8.0000	14.20000	19.38000	7.20000	-0.43266	5.7435	-0.44602	-0.43266	5.7435	0.0	*
		2	219 Line 1	0.0	6.34000	-4.21000	7.20000	-2.4489	-3.6699	-0.10216	-2.4489	-3.6699	0.0	*
				5.6200	11.96000	-4.21000	7.20000	-1.1678	-4.5306	-0.17336	-1.1678	-4.5306	0.0	*
				11.240	17.58000	-4.21000	7.20000	0.30930	-4.2177	-0.13138	0.30930	-4.2177	0.0	*
		3	219B Line 1	0.0	41.34000	-0.75000	7.20000	-0.045602	-1.4338	-0.013414	-0.014429	-1.4345	358.75	*
				2.7607	44.10000	-0.81000	7.20000	-0.55679	-1.8552	-0.13781	-0.51634	-1.8669	358.75	*
				5.5213	46.86000	-0.87000	7.20000	-0.94276	-2.7921	-0.37264	-0.88186	-2.8120	358.75	*
		4	215 Line 1	0.0	6.20000	19.38000	5.20000	-1.1111	1.4834	-0.26016	-1.1111	1.4834	0.0	*
				4.0000	10.20000	19.38000	5.20000	-0.73274	1.8561	-0.40638	-0.73274	1.8561	0.0	*
				8.0000	14.20000	19.38000	5.20000	-0.22582	1.9515	-0.42795	-0.22582	1.9515	0.0	*
		5	219 Line 1	0.0	6.34000	-4.21000	5.20000	-0.89128	-1.3016	-0.093069	-0.89128	-1.3016	0.0	*
				5.6200	11.96000	-4.21000	5.20000	-0.46668	-1.5896	-0.16165	-0.46668	-1.5896	0.0	*
				11.240	17.58000	-4.21000	5.20000	0.0077495	-1.5113	-0.12062	0.0077495	-1.5113	0.0	*
		6	219B Line 1	0.0	41.34000	-0.75000	5.20000	0.94250	-0.14581	-0.0087742	0.94544	-0.12529	358.75	*
				2.7607	44.10000	-0.81000	5.20000	0.99512	-0.019300	-0.13310	0.99531	0.0023327	358.75	*
				5.5213	46.86000	-0.87000	5.20000	1.0352	0.23888	-0.37085	1.0297	0.26133	358.75	*

* Result includes imported displacement(s).


RAW RESULTS
Legend
Building Results
< Sensitivity
Cat. 0 (Negligible)
Cat. 1 (Very Slight)
Cat. 2 (Slight)
Cat. 3 (Moderate)
Cat. 4 (Severe)
Displacement - Horizontal
0 : 0.5000 mm
0.5000 : 1.000 mm
1.000 : 1.500 mm
1.500 : 2.000 mm
2.000 : 2.500 mm
2.500 : 3.000 mm
3.000 : 3.500 mm
3.500 : 4.000 mm
4.000 : 4.500 mm
4.500 : 5.000 mm
Displacement Grids
Displacement Lines
Imp. Displacements

y
z
x

Displacement Results - Displacement Lines

Stage: Ref.	Stage: Name	Disp. Line: Ref.	Disp. Line: Name	Chainage [m]	x [m]	y [m]	z [m]	δx [mm]	δy [mm]	δz [mm]	δH// [mm]	δHperp. [mm]	Angle [°]	
0	Base Model	1	215 Line 1	0.0	6.20000	19.38000	7.20000	-0.22328	-0.29283	0.039604	-0.22328	-0.29283	0.0	*
				4.0000	10.20000	19.38000	7.20000	-0.41481	-0.47496	0.068971	-0.41481	-0.47496	0.0	*
				8.0000	14.20000	19.38000	7.20000	-0.73549	-0.42253	0.067580	-0.73549	-0.42253	0.0	*
		2	219 Line 1	0.0	6.34000	-4.21000	7.20000	-0.36771	0.20541	0.015411	-0.36771	0.20541	0.0	*
				5.6200	11.96000	-4.21000	7.20000	-0.56429	0.26678	0.027226	-0.56429	0.26678	0.0	*
				11.240	17.58000	-4.21000	7.20000	-0.75958	0.13112	0.020571	-0.75958	0.13112	0.0	*
		3	219B Line 1	0.0	41.34000	-0.75000	7.20000	-1.3756	-0.76518	-0.096814	-1.3586	-0.79490	358.75	*
				2.7607	44.10000	-0.81000	7.20000	-1.6384	-1.2870	-0.21434	-1.6100	-1.3223	358.75	*
				5.5213	46.86000	-0.87000	7.20000	-1.7174	-2.3173	-0.41724	-1.6666	-2.3541	358.75	*
		4	215 Line 2	0.0	6.20000	19.38000	5.20000	-0.057944	-0.11319	0.038086	-0.057944	-0.11319	0.0	*
				4.0000	10.20000	19.38000	5.20000	-0.13476	-0.16679	0.066956	-0.13476	-0.16679	0.0	*
				8.0000	14.20000	19.38000	5.20000	-0.25561	-0.14557	0.065668	-0.25561	-0.14557	0.0	*
		5	219 Line 2	0.0	6.34000	-4.21000	5.20000	-0.10156	0.092262	0.014577	-0.10156	0.092262	0.0	*
				5.6200	11.96000	-4.21000	5.20000	-0.19035	0.11066	0.026141	-0.19035	0.11066	0.0	*
				11.240	17.58000	-4.21000	5.20000	-0.28919	0.055308	0.019807	-0.28919	0.055308	0.0	*
		6	219B Line 2	0.0	41.34000	-0.75000	5.20000	0.11854	0.13249	-0.096728	0.11563	0.13503	358.75	*
				2.7607	44.10000	-0.81000	5.20000	0.19358	0.23351	-0.21457	0.18846	0.23766	358.75	*
				5.5213	46.86000	-0.87000	5.20000	0.25607	0.48906	-0.42376	0.24538	0.49451	358.75	*

* Result includes imported displacement(s).

Specific Building Damage Results - Critical Segments within Each Building

Stage: Ref.	Stage: Name	Specific Building: Ref.	Specific Building: Name	Parameter	Critical Sub-Building	Critical Segment	Start [m]	End [m]	Curvature	Max Slope	Max Settlement [mm]	Max Tensile Strain [%]	Min Radius of Curvature (Hogging) [m]	Min Radius of Curvature (Sagging) [m]	Damage Category
0	Base Model	0	215 KR	All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
		0	219A KR	All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
		0	219B KR	Max Slope	GL	1	2.7607	5.5000	None	**73.497E-6**	0.41567	409.81E-6	-	-	0 (Negligible)
				Max Settlement	GL	1	2.7607	5.5000	None	73.497E-6	**0.41567**	409.81E-6	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	2.7607	5.5000	None	73.497E-6	0.41567	**409.81E-6**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-
		0	215 KRB	All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
		0	219A KRB	All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
				All vertical displacements are less than the limit sensitivity.											
		0	219B KRB	Max Slope	BL	1	2.7607	5.5000	None	**75.774E-6**	0.42215	0.0020618	-	-	0 (Negligible)
				Max Settlement	BL	1	2.7607	5.5000	None	75.774E-6	**0.42215**	0.0020618	-	-	0 (Negligible)
				Max Tensile Strain	BL	1	2.7607	5.5000	None	75.774E-6	0.42215	**0.0020618**	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)		-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)		-	-	-	-	-	-	-	-	-	-

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Displacement Results - Displacement Grids

START_TABLE

Stage: Ref.	Stage: Name	Disp. Grid: Ref.	Disp. Grid: Name					
x	y	z	dx	dy	dz			
			[m]	[m]	[m]	[mm]	[mm]	[mm]
0	Base Model	1	Grid 1	0.00000	-5.00000	7.20000	-2.6305	-2.2235
0.019218	*							
			1.42000	-5.00000	7.20000	-2.6296	-2.4841	0.0041924
*								
			2.84000	-5.00000	7.20000	-2.5915	-2.7668	-0.013901
*								
			4.26000	-5.00000	7.20000	-2.5058	-3.0632	-0.034362
*								
			5.68000	-5.00000	7.20000	-2.3647	-3.3601	-0.055892
*								
			7.10000	-5.00000	7.20000	-2.1648	-3.6400	-0.076724
*								
			8.52000	-5.00000	7.20000	-1.9094	-3.8848	-0.094953
*								
			9.94000	-5.00000	7.20000	-1.6078	-4.0784	-0.10892
*								
			11.36000	-5.00000	7.20000	-1.2732	-4.2094	-0.11748
*								
			12.78000	-5.00000	7.20000	-0.92074	-4.2716	-0.12001
*								
			14.20000	-5.00000	7.20000	-0.56604	-4.2634	-0.11647
*								
			15.62000	-5.00000	7.20000	-0.22381	-4.1878	-0.10725
*								
			17.04000	-5.00000	7.20000	0.093010	-4.0516	-0.093178
*								
			18.46000	-5.00000	7.20000	0.37422	-3.8649	-0.075388
*								
			19.88000	-5.00000	7.20000	0.61290	-3.6395	-0.055163
*								
			21.30000	-5.00000	7.20000	0.80550	-3.3885	-0.033837
*								
			22.72000	-5.00000	7.20000	0.93950	-3.1292	-0.012704
*								
			24.14000	-5.00000	7.20000	1.0114	-2.8772	0.0070829
*								

```
                                    25.56000        -5.00000        7.20000 1.0421
-2.6376 0.024622        *
                                    26.98000        -5.00000        7.20000 1.0393
-2.4178 0.039342        *
                                    28.40000        -5.00000        7.20000 1.0115
-2.2221 0.050988        *
                                    29.82000        -5.00000        7.20000 0.96667
-2.0517 0.059541        *
                                    31.24000        -5.00000        7.20000 0.91178
-1.9062 0.065111        *
                                    32.66000        -5.00000        7.20000 0.85292
-1.7838 0.067834        *
                                    34.08000        -5.00000        7.20000 0.79554
-1.6818 0.067796        *
                                    35.50000        -5.00000        7.20000 0.74480
-1.5968 0.082690        *
                                    36.92000        -5.00000        7.20000 0.62915
-1.5636 0.078045        *
                                    38.34000        -5.00000        7.20000 0.51463
-1.5594 0.070540        *
                                    39.76000        -5.00000        7.20000 0.40371
-1.5849 0.059781        *
                                    41.18000        -5.00000        7.20000 0.29672
-1.6397 0.045280        *
                                    42.60000        -5.00000        7.20000 0.20031
-1.7262 0.026569        *
                                    44.02000        -5.00000        7.20000 0.11908
-1.8436 0.0034309       *
                                    45.44000        -5.00000        7.20000 0.069349
-1.9911 -0.023746       *
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2.4803  -4.5057 *
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2.3060  -4.1702 *
                                19.88000        10.18000        7.20000 6.0310
2.0571  -3.6594 *
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1.7285  -2.8229 *
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5.2945  -3.1286 *
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68.16000        12.20400        7.20000 2.7954
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71.00000        12.20400        7.20000 2.2764
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1.0047  0.026227        *
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0.93378 0.038945        *
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0.88810 0.064747        *
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0.89230 0.059903        *
                                        38.34000        13.21600        7.20000 0.65713
0.92957 0.046447        *
                                        39.76000        13.21600        7.20000 0.38290
1.0047  0.022829        *
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1.3145  -0.070132       *
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1.6002  -0.15420        *
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2.0456  -0.27946        *
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2.7351  -0.45408        *
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3.5414  -0.64661        *
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4.1210  -0.80074        *
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4.4765  -0.90405        *
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4.8028  -1.0053 *
                                        55.38000        13.21600        7.20000 0.90806
4.8401  -1.0201 *
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4.8080  -1.0153 *
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4.7024  -0.98975        *
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4.5067  -0.93865        *
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3.6643  -0.71888        *
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2.0992  -0.35501        *
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1.2026  -0.12599        *
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0.95515 -0.065323       *
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-0.17736        *
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-0.31093        *
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-0.88190        *
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-1.4910 *
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-2.2844 *
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-2.6912 *
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-2.9218 *
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9.4551  -3.0412 *
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9.6372  -3.0797 *
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0.0065113       9.6524  -3.0387 *
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9.4849  -2.8811 *
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8.9373  -2.4107 *
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8.3835  -2.1206 *
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7.5582  -1.8090 *
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6.2150  -1.3929 *
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1.7034  -0.089519       *
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1.0258  0.068144        *
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4.1311  -0.70053        *
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4.0287  -0.68054        *
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3.1330  -0.48679        *
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1.5779  -0.16246        *
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1.0158  -0.046388       *
                                71.00000        14.22800        7.20000 2.0594
0.83787 -0.013835       *
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-0.14590        *
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-0.25643        *
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-0.42730        *
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-0.69188        *
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-1.0763 *
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-1.4867 *
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-1.7781 *
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9.3352  -2.0791 *
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-0.070606       9.3020  -2.0428 *
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8.9886  -1.9217 *
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8.2633  -1.7112 *
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7.5649  -1.4926 *
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6.7511  -1.2581 *
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1.6360  -0.015710       *
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1.3155  0.037372        *
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2.7371  -0.32870        *
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0.88379 -0.0030023      *
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-0.76236        *
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-1.0130 *
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-1.2101 *
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-1.3398 *
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5.1999  -0.68485        *
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4.2768  -0.49185        *
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2.4432  -0.22035        *
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55.38000        17.26400        7.20000 0.90415
56.80000        17.26400        7.20000 1.1066
58.22000        17.26400        7.20000 1.3072
59.64000        17.26400        7.20000 1.4983
61.06000        17.26400        7.20000 1.6695
62.48000        17.26400        7.20000 1.8067
63.90000        17.26400        7.20000 1.8961
65.32000        17.26400        7.20000 1.9318
66.74000        17.26400        7.20000 1.9206
68.16000        17.26400        7.20000 1.8784
69.58000        17.26400        7.20000 1.8164
71.00000        17.26400        7.20000 1.7451
0.00000 18.27600        7.20000 -3.5226 2.2727
1.42000 18.27600        7.20000 -3.6708 2.6812
2.84000 18.27600        7.20000 -3.7789 3.1831
4.26000 18.27600        7.20000 -3.8023 3.7830
5.68000 18.27600        7.20000 -3.6812 4.4519
7.10000 18.27600        7.20000 -3.3767 5.1133
```

```
                                    8.52000 18.27600        7.20000 -2.9080 5.6797
-0.56551        *
                                    9.94000 18.27600        7.20000 -2.3309 6.1035
-0.63026        *
                                    11.36000        18.27600        7.20000 -1.6942
6.3738  -0.66906        *
                                    12.78000        18.27600        7.20000 -1.0303
6.4926  -0.68218        *
                                    14.20000        18.27600        7.20000 -0.36472
6.4603  -0.67000        *
                                    15.62000        18.27600        7.20000 0.27224
6.2784  -0.63344        *
                                    17.04000        18.27600        7.20000 0.84598
5.9627  -0.57609        *
                                    18.46000        18.27600        7.20000 1.3354
5.5426  -0.50375        *
                                    19.88000        18.27600        7.20000 1.7310
5.0409  -0.42110        *
                                    21.30000        18.27600        7.20000 2.0154
4.4795  -0.33222        *
                                    22.72000        18.27600        7.20000 2.1597
3.9041  -0.24358        *
                                    24.14000        18.27600        7.20000 2.1669
3.3700  -0.16309        *
                                    25.56000        18.27600        7.20000 2.0860
2.9075  -0.096050       *
                                    26.98000        18.27600        7.20000 1.9548
2.5263  -0.043747       *
                                    28.40000        18.27600        7.20000 1.8010
2.2205  -0.0048106      *
                                    29.82000        18.27600        7.20000 1.6422
1.9783  0.023035        *
                                    31.24000        18.27600        7.20000 1.4887
1.7881  0.042022        *
                                    32.66000        18.27600        7.20000 1.3464
1.6395  0.053986        *
                                    34.08000        18.27600        7.20000 1.2194
1.5234  0.060291        *
                                    35.50000        18.27600        7.20000 1.1109
1.4323  0.080531        *
                                    36.92000        18.27600        7.20000 0.94750
1.3993  0.078714        *
                                    38.34000        18.27600        7.20000 0.79467
1.3977  0.073295        *
                                    39.76000        18.27600        7.20000 0.65340
1.4269  0.064258        *
                                    41.18000        18.27600        7.20000 0.52205
1.4851  0.051428        *
                                    42.60000        18.27600        7.20000 0.40640
1.5736  0.034602        *
                                    44.02000        18.27600        7.20000 0.30946
1.6907  0.013768        *
                                    45.44000        18.27600        7.20000 0.24608
1.8342  -0.010589       *
```

```
                                    46.86000        18.27600        7.20000 0.22567
1.9948  -0.037212      *
                                    48.28000        18.27600        7.20000 0.25279
2.1579  -0.064099      *
                                    49.70000        18.27600        7.20000 0.32559
2.3070  -0.089002      *
                                    51.12000        18.27600        7.20000 0.43624
2.4290  -0.11009       *
                                    52.54000        18.27600        7.20000 0.57466
2.5162  -0.12629       *
                                    53.96000        18.27600        7.20000 0.73144
2.5652  -0.13714       *
                                    55.38000        18.27600        7.20000 0.89884
2.5748  -0.14253       *
                                    56.80000        18.27600        7.20000 1.0703
2.5447  -0.14247       *
                                    58.22000        18.27600        7.20000 1.2396
2.4747  -0.13695       *
                                    59.64000        18.27600        7.20000 1.3994
2.3650  -0.12604       *
                                    61.06000        18.27600        7.20000 1.5411
2.2173  -0.11006       *
                                    62.48000        18.27600        7.20000 1.6550
2.0373  -0.089846      *
                                    63.90000        18.27600        7.20000 1.7326
1.8358  -0.067005      *
                                    65.32000        18.27600        7.20000 1.7703
1.6275  -0.043687      *
                                    66.74000        18.27600        7.20000 1.7723
1.4275  -0.021991      *
                                    68.16000        18.27600        7.20000 1.7485
1.2460  -0.0033515     *
                                    69.58000        18.27600        7.20000 1.7057
1.0868  0.011645       *
                                    71.00000        18.27600        7.20000 1.6519
0.95008 0.023059       *
                                    0.00000 19.28800        7.20000 -3.2696 2.3018
-0.033792      *
                                    1.42000 19.28800        7.20000 -3.3637 2.6727
-0.073632      *
                                    2.84000 19.28800        7.20000 -3.4130 3.1111
-0.12507       *
                                    4.26000 19.28800        7.20000 -3.3855 3.6121
-0.18758       *
                                    5.68000 19.28800        7.20000 -3.2464 4.1496
-0.25721       *
                                    7.10000 19.28800        7.20000 -2.9756 4.6742
-0.32633       *
                                    8.52000 19.28800        7.20000 -2.5830 5.1309
-0.38648       *
                                    9.94000 19.28800        7.20000 -2.1002 5.4826
-0.43179       *
                                    11.36000        19.28800        7.20000 -1.5615
5.7133  -0.45970       *
```

5.8184	-0.46957	*
5.7977	-0.46157	*
5.6551	-0.43668	*
5.4031	-0.39725	*
5.0614	-0.34671	*
4.6504	-0.28849	*
4.1929	-0.22613	*
3.7244	-0.16399	*
3.2824	-0.10674	*
2.8870	-0.057770	*
2.5495	-0.018397	*
2.2698	0.011721	*
2.0420	0.033729	*
1.8586	0.048969	*
1.7117	0.058661	*
1.5941	0.063774	*
1.4989	0.082738	*
1.4606	0.081203	*
1.4515	0.076755	*
1.4704	0.069455	*
1.5145	0.059275	*
1.5838	0.046196	*
1.6754	0.030354	*
1.7869	0.012214	*
1.9106	-0.0073152	*
2.0356	-0.026932	*
2.1504	-0.045205	*

12.78000	19.28800	7.20000	-0.99578
14.20000	19.28800	7.20000	-0.42779
15.62000	19.28800	7.20000	0.11693
17.04000	19.28800	7.20000	0.61335
18.46000	19.28800	7.20000	1.0429
19.88000	19.28800	7.20000	1.3932
21.30000	19.28800	7.20000	1.6526
22.72000	19.28800	7.20000	1.8024
24.14000	19.28800	7.20000	1.8433
25.56000	19.28800	7.20000	1.8108
26.98000	19.28800	7.20000	1.7299
28.40000	19.28800	7.20000	1.6221
29.82000	19.28800	7.20000	1.5030
31.24000	19.28800	7.20000	1.3829
32.66000	19.28800	7.20000	1.2688
34.08000	19.28800	7.20000	1.1658
35.50000	19.28800	7.20000	1.0778
36.92000	19.28800	7.20000	0.93592
38.34000	19.28800	7.20000	0.80366
39.76000	19.28800	7.20000	0.68260
41.18000	19.28800	7.20000	0.57146
42.60000	19.28800	7.20000	0.47552
44.02000	19.28800	7.20000	0.39642
45.44000	19.28800	7.20000	0.34637
46.86000	19.28800	7.20000	0.33161
48.28000	19.28800	7.20000	0.35460
49.70000	19.28800	7.20000	0.41398

```
                                51.12000        19.28800        7.20000 0.50456
2.2450  -0.060908       *
                                52.54000        19.28800        7.20000 0.61919
2.3126  -0.073216       *
                                53.96000        19.28800        7.20000 0.75056
2.3495  -0.081687       *
                                55.38000        19.28800        7.20000 0.89192
2.3536  -0.086139       *
                                56.80000        19.28800        7.20000 1.0372
2.3244  -0.086522       *
                                58.22000        19.28800        7.20000 1.1802
2.2617  -0.082866       *
                                59.64000        19.28800        7.20000 1.3148
2.1664  -0.075306       *
                                61.06000        19.28800        7.20000 1.4338
2.0409  -0.064192       *
                                62.48000        19.28800        7.20000 1.5302
1.8904  -0.050215       *
                                63.90000        19.28800        7.20000 1.5984
1.7231  -0.034475       *
                                65.32000        19.28800        7.20000 1.6361
1.5494  -0.018347       *
                                66.74000        19.28800        7.20000 1.6458
1.3798  -0.0031641      *
                                68.16000        19.28800        7.20000 1.6344
1.2224  0.010094        *
                                69.58000        19.28800        7.20000 1.6057
1.0806  0.020934        *
                                71.00000        19.28800        7.20000 1.5655
0.95586 0.029281        *
                                0.00000 20.30000        7.20000 -3.0371 2.3078
-0.013576       *
                                1.42000 20.30000        7.20000 -3.0907 2.6413
-0.043289       *
                                2.84000 20.30000        7.20000 -3.0997 3.0228
-0.080567       *
                                4.26000 20.30000        7.20000 -3.0423 3.4442
-0.12453        *
                                5.68000 20.30000        7.20000 -2.8970 3.8839
-0.17237        *
                                7.10000 20.30000        7.20000 -2.6529 4.3082
-0.21949        *
                                8.52000 20.30000        7.20000 -2.3158 4.6804
-0.26086        *
                                9.94000 20.30000        7.20000 -1.9055 4.9722
-0.29258        *
                                11.36000        20.30000        7.20000 -1.4464
5.1678  -0.31250        *
                                12.78000        20.30000        7.20000 -0.96205
5.2604  -0.31978        *
                                14.20000        20.30000        7.20000 -0.47444
5.2488  -0.31441        *
                                15.62000        20.30000        7.20000
-0.0048505      5.1368  -0.29715        *
```

4.9342	-0.26955	*
4.6556	-0.23384	*
4.3183	-0.19250	*
3.9422	-0.14822	*
3.5558	-0.10400	*
3.1867	-0.062800	*
2.8482	-0.026878	*
2.5509	0.0026712	*
2.2975	0.025766	*
2.0859	0.042943	*
1.9114	0.054988	*
1.7683	0.062694	*
1.6509	0.066738	*
1.5530	0.084452	*
1.5104	0.083118	*
1.4947	0.079449	*
1.5042	0.073546	*
1.5355	0.065458	*
1.5880	0.055253	*
1.6581	0.043118	*
1.7436	0.029448	*
1.8384	0.014900	*
1.9341	345.96E-6	*
2.0221	-0.013268	*
2.0945	-0.025105	*
2.1458	-0.034551	*
2.1721	-0.041231	*

17.04000	20.30000	7.20000	0.42701
18.46000	20.30000	7.20000	0.80534
19.88000	20.30000	7.20000	1.1185
21.30000	20.30000	7.20000	1.3582
22.72000	20.30000	7.20000	1.5095
24.14000	20.30000	7.20000	1.5716
25.56000	20.30000	7.20000	1.5724
26.98000	20.30000	7.20000	1.5292
28.40000	20.30000	7.20000	1.4581
29.82000	20.30000	7.20000	1.3722
31.24000	20.30000	7.20000	1.2813
32.66000	20.30000	7.20000	1.1926
34.08000	20.30000	7.20000	1.1114
35.50000	20.30000	7.20000	1.0423
36.92000	20.30000	7.20000	0.92030
38.34000	20.30000	7.20000	0.80683
39.76000	20.30000	7.20000	0.70376
41.18000	20.30000	7.20000	0.60998
42.60000	20.30000	7.20000	0.53020
44.02000	20.30000	7.20000	0.46498
45.44000	20.30000	7.20000	0.42471
46.86000	20.30000	7.20000	0.41377
48.28000	20.30000	7.20000	0.43347
49.70000	20.30000	7.20000	0.48271
51.12000	20.30000	7.20000	0.55780
52.54000	20.30000	7.20000	0.65348
53.96000	20.30000	7.20000	0.76397

```
                                55.38000        20.30000        7.20000 0.88355
2.1714  -0.044956       *
                                56.80000        20.30000        7.20000 1.0067
2.1428  -0.045668       *
                                58.22000        20.30000        7.20000 1.1281
2.0864  -0.043402       *
                                59.64000        20.30000        7.20000 1.2421
2.0031  -0.038306       *
                                61.06000        20.30000        7.20000 1.3430
1.8954  -0.030694       *
                                62.48000        20.30000        7.20000 1.4257
1.7679  -0.021098       *
                                63.90000        20.30000        7.20000 1.4862
1.6267  -0.010285       *
                                65.32000        20.30000        7.20000 1.5227
1.4795  837.50E-6       *
                                66.74000        20.30000        7.20000 1.5370
1.3340  0.011393        *
                                68.16000        20.30000        7.20000 1.5339
1.1965  0.020707        *
                                69.58000        20.30000        7.20000 1.5155
1.0701  0.028391        *
                                71.00000        20.30000        7.20000 1.4860
0.95652 0.034329        *
END_TABLE
* Result includes imported displacement(s).
```

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Specific Building Damage Results - Critical Segments within Each Building

START_TABLE

Stage: Ref.	Stage: Name	Specific Building: Ref.	Specific Building: Name	Parameter	Critical Sub-Building	Critical Segment	Start	End	Curvature	Max Slope	Max Settlement	Max Tensile Strain	Min Radius of Curvature (Hogging)	Min Radius of Curvature (Sagging)	Damage Category
							[m]	[m]							
[mm]	[%]	[m]	[m]												
0	Base Model	0	215 KR	Max Slope	GL	1	0.0	7.9900	None	37.487E-6	0.44596	0.034522	-	-	0 (Negligible)
				Max Settlement	GL	1	0.0	7.9900	None	37.487E-6	0.44596	0.034522	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	0.0	7.9900	None	37.487E-6	0.44596	0.034522	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)											
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)											
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0	219A KR	Max Slope	GL	1	0.0	11.200	None	12.664E-6	0.17308	0.025185	-	-	0 (Negligible)
				Max Settlement	GL	1	0.0	11.200	None	12.664E-6	0.17308	0.025185	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	0.0	11.200	None	12.664E-6	0.17308	0.025185	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)											
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
				Min Radius of Curvature (Sagging)											
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		0	219B KR	Max Slope	GL	1	2.7607	5.5000	None	85.076E-6	0.37083	0.0026481	-	-	0 (Negligible)
				Max Settlement	GL	1	2.7607	5.5000	None	85.076E-6	0.37083	0.0026481	-	-	0 (Negligible)
				Max Tensile Strain	GL	1	2.7607	5.5000	None	85.076E-6	0.37083	0.0026481	-	-	0 (Negligible)
				Min Radius of Curvature (Hogging)											
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

```
                                Min Radius of Curvature (Sagging)
-       -       -       -       -       -       -       -       -       -
                0       215 KRB Max Slope       BL      1       0.0     7.9900
None    36.551E-6       0.42789 0.011996        -       -       0 (Negligible)
                                Max Settlement  BL      1       0.0     7.9900
None    36.551E-6       0.42789 0.011996        -       -       0 (Negligible)
                                Max Tensile Strain      BL      1       0.0
7.9900  None    36.551E-6       0.42789 0.011996        -       -       0
(Negligible)
                                Min Radius of Curvature (Hogging)
-       -       -       -       -       -       -       -       -       -
                                Min Radius of Curvature (Sagging)
-       -       -       -       -       -       -       -       -       -
                0       219A KRB        Max Slope       BL      1       5.6200
11.200  None    12.202E-6       0.16165 0.0084417       -       -       0
(Negligible)
                                Max Settlement  BL      1       5.6200  11.200
None    12.202E-6       0.16165 0.0084417       -       -       0 (Negligible)
                                Max Tensile Strain      BL      1       5.6200
11.200  None    12.202E-6       0.16165 0.0084417       -       -       0
(Negligible)
                                Min Radius of Curvature (Hogging)
-       -       -       -       -       -       -       -       -       -
                                Min Radius of Curvature (Sagging)
-       -       -       -       -       -       -       -       -       -
                0       219B KRB        Max Slope       BL      1       2.7607
5.5000  None    86.120E-6       0.36902 0.0012470       -       -       0
(Negligible)
                                Max Settlement  BL      1       2.7607  5.5000
None    86.120E-6       0.36902 0.0012470       -       -       0 (Negligible)
                                Max Tensile Strain      BL      1       2.7607
5.5000  None    86.120E-6       0.36902 0.0012470       -       -       0
(Negligible)
                                Min Radius of Curvature (Hogging)
-       -       -       -       -       -       -       -       -       -
                                Min Radius of Curvature (Sagging)
-       -       -       -       -       -       -       -       -       -
END_TABLE
```

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File XDisp Long Term.xdd
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Displacement Results - Displacement Grids

START_TABLE
Stage: Ref. Stage: Name Disp. Grid: Ref. Disp. Grid: Name
x y z dx dy dz
[m] [m] [m] [mm] [mm] [mm]

0 Base Model 1 Grid 1 0.00000 -5.00000 7.20000 -0.30519 0.086238 0.0014580 *
1.42000 -5.00000 7.20000 -0.31488 0.10408 0.0031513 *
2.84000 -5.00000 7.20000 -0.32776 0.12417 0.0052860 *
4.26000 -5.00000 7.20000 -0.34503 0.14624 0.0078628 *
5.68000 -5.00000 7.20000 -0.36814 0.16947 0.010808 *
7.10000 -5.00000 7.20000 -0.39856 0.19212 0.013941 *
8.52000 -5.00000 7.20000 -0.43716 0.21136 0.016959 *
9.94000 -5.00000 7.20000 -0.48349 0.22369 0.019485 *
11.36000 -5.00000 7.20000 -0.53534 0.22577 0.021165 *
12.78000 -5.00000 7.20000 -0.58899 0.21557 0.021782 *
14.20000 -5.00000 7.20000 -0.64009 0.19302 0.021328 *
15.62000 -5.00000 7.20000 -0.68478 0.16009 0.020012 *
17.04000 -5.00000 7.20000 -0.72051 0.12013 0.018188 *
18.46000 -5.00000 7.20000 -0.74641 0.076916 0.016254 *
19.88000 -5.00000 7.20000 -0.76303 0.033721 0.014540 *
21.30000 -5.00000 7.20000 -0.76585 -0.0054132 0.013255 *
22.72000 -5.00000 7.20000 -0.76717 -0.042972 0.012472 *
24.14000 -5.00000 7.20000 -0.77841 -0.082618 0.012154 *

```
                                25.56000        -5.00000        7.20000 -0.78788
-0.12052        0.012194        *
                                26.98000        -5.00000        7.20000 -0.79603
-0.15732        0.012446        *
                                28.40000        -5.00000        7.20000 -0.80283
-0.19366        0.012745        *
                                29.82000        -5.00000        7.20000 -0.80786
-0.23003        0.012914        *
                                31.24000        -5.00000        7.20000 -0.81031
-0.26671        0.012756        *
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-1.0380 -0.057287       *
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0.097293        0.0022968
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69.58000        -5.00000        7.20000 0.63450
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-0.64393        0.43394 *
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1.6458  -0.27824        *
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0.45825 -0.028833       *
0.37560 -0.011583       *
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0.095852        *
0.15482 *
0.34728 *
0.48094 *
-1.6368 0.53368 *
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68.16000        13.21600        7.20000 1.0253
69.58000        13.21600        7.20000 0.92308
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1.42000 14.22800        7.20000 -0.061572
*
2.84000 14.22800        7.20000 -0.0048634
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4.26000 14.22800        7.20000 0.071103
*
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9.94000 14.22800        7.20000 0.10121 -1.4915
11.36000        14.22800        7.20000 -0.39570
12.78000        14.22800        7.20000 -0.88553
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0.22065 *
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*
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1.2907  -0.10696        *
                                46.86000        17.26400        7.20000 -0.82618
1.4877  -0.13466        *
                                48.28000        17.26400        7.20000 -0.67170
1.6606  -0.15886        *
                                49.70000        17.26400        7.20000 -0.47217
1.7790  -0.17536        *
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1.8268  -0.18187        *
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1.7459  -0.16921        *
                                55.38000        17.26400        7.20000 0.26460
1.6584  -0.15566        *
                                56.80000        17.26400        7.20000 0.38119
1.5596  -0.14038        *
                                58.22000        17.26400        7.20000 0.47928
1.4542  -0.12434        *
                                59.64000        17.26400        7.20000 0.56292
1.3421  -0.10773        *
                                61.06000        17.26400        7.20000 0.63248
1.2220  -0.090504       *
                                62.48000        17.26400        7.20000 0.68520
1.0941  -0.072737       *
                                63.90000        17.26400        7.20000 0.71726
0.96212 -0.054979       *
                                65.32000        17.26400        7.20000 0.72727
0.83348 -0.038194       *
                                66.74000        17.26400        7.20000 0.71830
0.71573 -0.023367       *
                                68.16000        17.26400        7.20000 0.69634
0.61314 -0.011079       *
                                69.58000        17.26400        7.20000 0.66690
0.52629 -0.0014208      *
                                71.00000        17.26400        7.20000 0.63412
0.45375 0.0058404       *
                                0.00000 18.27600        7.20000 -0.18588
-0.085017       0.0091946       *
                                1.42000 18.27600        7.20000 -0.17377
-0.11916        0.014915        *
                                2.84000 18.27600        7.20000 -0.16207
-0.16418        0.022748        *
                                4.26000 18.27600        7.20000 -0.15354
-0.22379        0.033269        *
                                5.68000 18.27600        7.20000 -0.15455
-0.30228        0.046994        *
                                7.10000 18.27600        7.20000 -0.17824
-0.40069        0.063796        *
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```
-0.50759        0.081758
-0.59610        0.096968
-0.63914        0.10548 *
-0.62309        0.10518 *
-0.54831        0.096125
-0.42890        0.080465
-0.29191        0.062155
-0.16484        0.045218
-0.062194       0.031966
0.012461        0.022877
0.067893        0.017327
0.11502 0.014299        *
0.15521 0.012857        *
0.19203 0.012323        *
0.22743 0.012230        *
0.26242 0.012240        *
0.29748 0.012073        *
0.33264 0.011471        *
0.36740 0.010167        *
0.40052 0.0069367       *
0.47014 0.0023233       *
0.55135 -0.0042510      *
0.64642 -0.013211       *
0.75742 -0.024922       *
0.88556 -0.039560       *
1.0298  -0.056889       *
1.1842  -0.075978       *
8.52000 18.27600        7.20000 -0.24229
*
9.94000 18.27600        7.20000 -0.35425
*
11.36000        18.27600        7.20000 -0.50164
12.78000        18.27600        7.20000 -0.66043
14.20000        18.27600        7.20000 -0.80461
*
15.62000        18.27600        7.20000 -0.91039
*
17.04000        18.27600        7.20000 -0.96516
*
18.46000        18.27600        7.20000 -0.97507
*
19.88000        18.27600        7.20000 -0.95707
*
21.30000        18.27600        7.20000 -0.92114
*
22.72000        18.27600        7.20000 -0.88806
*
24.14000        18.27600        7.20000 -0.87214
25.56000        18.27600        7.20000 -0.86116
26.98000        18.27600        7.20000 -0.85382
28.40000        18.27600        7.20000 -0.84855
29.82000        18.27600        7.20000 -0.84384
31.24000        18.27600        7.20000 -0.83816
32.66000        18.27600        7.20000 -0.82980
34.08000        18.27600        7.20000 -0.81666
35.50000        18.27600        7.20000 -0.79602
36.92000        18.27600        7.20000 -0.81874
38.34000        18.27600        7.20000 -0.84083
39.76000        18.27600        7.20000 -0.85980
41.18000        18.27600        7.20000 -0.87183
42.60000        18.27600        7.20000 -0.87114
44.02000        18.27600        7.20000 -0.84936
45.44000        18.27600        7.20000 -0.79758
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1.6037  -0.12792        *
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1.5590  -0.12065        *
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1.4944  -0.11141        *
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                                58.22000        18.27600        7.20000 0.40767
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1.1270  -0.062771       *
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1.0181  -0.049492       *
                                63.90000        18.27600        7.20000 0.63112
0.90677 -0.036386       *
                                65.32000        18.27600        7.20000 0.64557
0.79800 -0.024049       *
                                66.74000        18.27600        7.20000 0.64473
0.69669 -0.013074       *
                                68.16000        18.27600        7.20000 0.63246
0.60608 -0.0038483      *
                                69.58000        18.27600        7.20000 0.61258
0.52725 0.0035166       *
                                71.00000        18.27600        7.20000 0.58836
0.45975 0.0091247       *
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                                1.42000 19.28800        7.20000 -0.19988
-0.11467        0.012012        *
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-0.15528        0.018264        *
                                4.26000 19.28800        7.20000 -0.19757
-0.20675        0.026378        *
                                5.68000 19.28800        7.20000 -0.20987
-0.27039        0.036460        *
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-0.34408        0.048092        *
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-0.41848        0.059905        *
                                9.94000 19.28800        7.20000 -0.39290
-0.47712        0.069669        *
                                11.36000        19.28800        7.20000 -0.50723
-0.50349        0.075166        *
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                                    15.62000        19.28800        7.20000 -0.82592
-0.34376        0.059797            *
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-0.24100        0.048125            *
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-0.14083        0.036871            *
                                    19.88000        19.28800        7.20000 -0.89286
-0.054226       0.027594            *
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0.013386        0.020857            *
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0.19698 0.012324        *
                                    28.40000        19.28800        7.20000 -0.81646
0.23361 0.012313        *
                                    29.82000        19.28800        7.20000 -0.81033
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0.30446 0.012437        *
                                    32.66000        19.28800        7.20000 -0.79141
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0.37240 0.011212        *
                                    35.50000        19.28800        7.20000 -0.75087
0.40308 0.0089830       *
                                    36.92000        19.28800        7.20000 -0.76669
0.46974 0.0054360       *
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0.54599 376.69E-6       *
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1.3878  -0.084737       *
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-0.088644       1.4293  -0.088138       *
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1.4027  -0.084246       *
                                55.38000        19.28800        7.20000 0.15912
1.3543  -0.077864       *
                                56.80000        19.28800        7.20000 0.26015
1.2908  -0.069904       *
                                58.22000        19.28800        7.20000 0.34679
1.2166  -0.060997       *
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1.1344  -0.051515       *
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1.0457  -0.041695       *
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0.95248 -0.031770       *
                                63.90000        19.28800        7.20000 0.55804
0.85747 -0.022055       *
                                65.32000        19.28800        7.20000 0.57557
0.76423 -0.012944       *
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0.59595 0.0020822       *
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0.52456 0.0076378       *
                                71.00000        19.28800        7.20000 0.54545
0.46214 0.011898        *
                                0.00000 20.30000        7.20000 -0.22451
-0.078028       0.0056421       *
                                1.42000 20.30000        7.20000 -0.22340
-0.10682        0.0094081       *
                                2.84000 20.30000        7.20000 -0.22562
-0.14244        0.014325        *
                                4.26000 20.30000        7.20000 -0.23392
-0.18571        0.020511        *
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-0.23634        0.027899        *
                                7.10000 20.30000        7.20000 -0.28687
-0.29138        0.036061        *
                                8.52000 20.30000        7.20000 -0.34157
-0.34367        0.044055        *
                                9.94000 20.30000        7.20000 -0.41714
-0.38261        0.050543        *
                                11.36000        20.30000        7.20000 -0.50792
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-0.38336        0.054364        *
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-0.33933        0.050957        *
                                15.62000        20.30000        7.20000 -0.76170
-0.27226        0.044822        *
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                                17.04000        20.30000        7.20000 -0.80820
-0.19294        0.037305        *
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-0.039639       0.023410        *
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0.020451        0.018563        *
                                22.72000        20.30000        7.20000 -0.80672
0.071554        0.015304        *
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0.11981 0.013384        *
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0.16258 0.012459        *
                                26.98000        20.30000        7.20000 -0.78967
0.20184 0.012193        *
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0.23896 0.012299        *
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0.27475 0.012539        *
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0.30952 0.012708        *
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0.34309 0.012619        *
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0.37466 0.012087        *
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0.40261 0.010731        *
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0.46590 0.0080910       *
                                38.34000        20.30000        7.20000 -0.72478
0.53698 0.0042944       *
                                39.76000        20.30000        7.20000 -0.72701
0.61664 -834.44E-6      *
                                41.18000        20.30000        7.20000 -0.72136
0.70512 -0.0073908      *
                                42.60000        20.30000        7.20000 -0.70414
0.80168 -0.015324       *
                                44.02000        20.30000        7.20000 -0.67079
0.90407 -0.024357       *
                                45.44000        20.30000        7.20000 -0.61801
1.0074  -0.033920       *
                                46.86000        20.30000        7.20000 -0.54351
1.1047  -0.043155       *
                                48.28000        20.30000        7.20000 -0.44813
1.1875  -0.051047       *
                                49.70000        20.30000        7.20000 -0.33647
1.2481  -0.056676       *
                                51.12000        20.30000        7.20000 -0.21612
1.2819  -0.059485       *
                                52.54000        20.30000        7.20000
-0.095374       1.2884  -0.059420       *
                                53.96000        20.30000        7.20000 0.019030
1.2708  -0.056858       *
```

```
                                55.38000        20.30000        7.20000 0.12308
1.2340  -0.052398       *
                                56.80000        20.30000        7.20000 0.21522
1.1828  -0.046636       *
                                58.22000        20.30000        7.20000 0.29527
1.1209  -0.040043       *
                                59.64000        20.30000        7.20000 0.36341
1.0509  -0.032948       *
                                61.06000        20.30000        7.20000 0.41963
0.97476 -0.025590       *
                                62.48000        20.30000        7.20000 0.46365
0.89461 -0.018187       *
                                63.90000        20.30000        7.20000 0.49531
0.81283 -0.010986       *
                                65.32000        20.30000        7.20000 0.51497
0.73213 -0.0042561      *
                                66.74000        20.30000        7.20000 0.52385
0.65510 0.0017543       *
                                68.16000        20.30000        7.20000 0.52393
0.58375 0.0068671       *
                                69.58000        20.30000        7.20000 0.51713
0.51915 0.011004        *
                                71.00000        20.30000        7.20000 0.50547
0.46163 0.014178        *
END_TABLE
* Result includes imported displacement(s).
```

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