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Settlement Analysis Report

Longcross Film Studios, Chobham Lane, Longcross, Chertsey, KT16 0EE

A REPORT PREPARED

FOR AND ON BEHALF OF ARK DATA CENTRES LTD C/O HURLEY PALMER FLATT

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ISSUING OFFICE:	Paragon, The Harlequin Building, 65 Southwark Street, London, SE1 0HR Tel: 020 7125 0112
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REPORT PREPARED BY:	Charlie Bruinvels BSc MSc CEnv C.WEM
REPORT CHECKED BY:	Charlie Knox MSc Env
SIGNATURE:	
	For and on behalf of Paragon Building Consultancy Limited

EXECUTIVE SUMMARY

KEY FINDINGS

1.	An analysis has been carried out to assess the feasibility of a raft foundation solution for the proposed development at Longcross Film Studios. The analysis has been undertaken using the three-dimensional finite element soil-structure-interaction analysis software PLAXIS 3D. The model has been based on the findings of the Phase 2 Site Investigation Report completed by Paragon (dated: 21 August 2020, reference: 20.0576/CB/NW) and the Serviceability Limit State (SLS) loads provided by the structural engineer. The key findings of the assessment are as follows: • Predicted settlements are relatively low for the proposed structure and considered to be within sustainable limits, with an average vertical settlement of 20mm predicted across the raft; • The maximum angular distortion across the raft is predicted to be 1/980, which is within acceptable limits for the proposed building construction type. • The recommended spring stiffnesses to be adopted initially to supplement structural modelling and detailing of the raft is 6MN/m3 however, this is likely to require adjustments/zoning in the structural model by the structural engineer so that the displacement magnitude and profile mimics that predicted in this assessment by the detailed geotechnical model. • Based on the findings of this assessment it is considered that a raft is a feasible foundation solution for the proposed development.

CONTENTS

PHASE 2 SITE INVESTIGATION REPORT

CLIENT NAME: Ark Data Centres LTD C/O Hurley Palmer Flatt

PROPERTY ADDRESS: Longcross Film Studios
Chobham Lane, Longcross, Chertsey

INVESTIGATION DATE: N/A

1.0 INSTRUCTIONS

1.1	Paragon Building Consultancy Limited were instructed by Ark Data Centres Limited c/o Hurley Palmer Flatt on 5 October 2020 to comission a Settlement Analysis on a site referred to as Longcross Film Studios, Chobham Lane, Longcross, Chertsey, KT16 0EE. These works have been completed in connection with redevelopment of the site as a Data Centre with HV Energy Centre, generator and water tanks.

2.0 INTRODUCTION

2.1	**Site Description**
2.1.1	The site is centred approximately at National Grid Reference: 497740, 165682, and extends to 3.5Ha. The site was historically used for military purposes and has since been used as Longcross Film Studios. The site is immediately surrounded by commercial properties relating to the wider Longcross Film Studios, with Chobham lane to the south. Paragon have completed previous Phase 1 and Phase 2 investigations which should be read in conjunction with this report: • Paragon, 2020. Phase 2 Site Investigation at Longcross Film Studios. Dated: 21 August 2020. Reference: 20.0576/CB/NW. • Paragon, 2020. Phase 1 Environmental Risk Assessment at Longcross Film Studios. Dated: 13 August 2020. Reference: 20.0576/CB/KJH.
2.1.2	At the time of the Phase 2 Investigation, the site comprised an exposed concrete slab in the centre, a shallow gradient slope in the northern part of the site with an exposed concrete slab and buildings, a car park in the eastern part of the site, canteen building and associated parking in the southern part, and a steep slope with office units in the west. Since the investigation, Crest Nicholson have been preparing the site for Ark. This has involved demolishing the buildings and preparing a formation level.

2.2 **Proposed Development**

2.2.1 The proposed development involves the construction of a three-storey data centre. The data centre consists of three blocks, with the total building footprint measuring approximately 71.3m wide and 196.5m long. The building comprises a streel framed structure, with a steel gantry along the longer sides of the building.

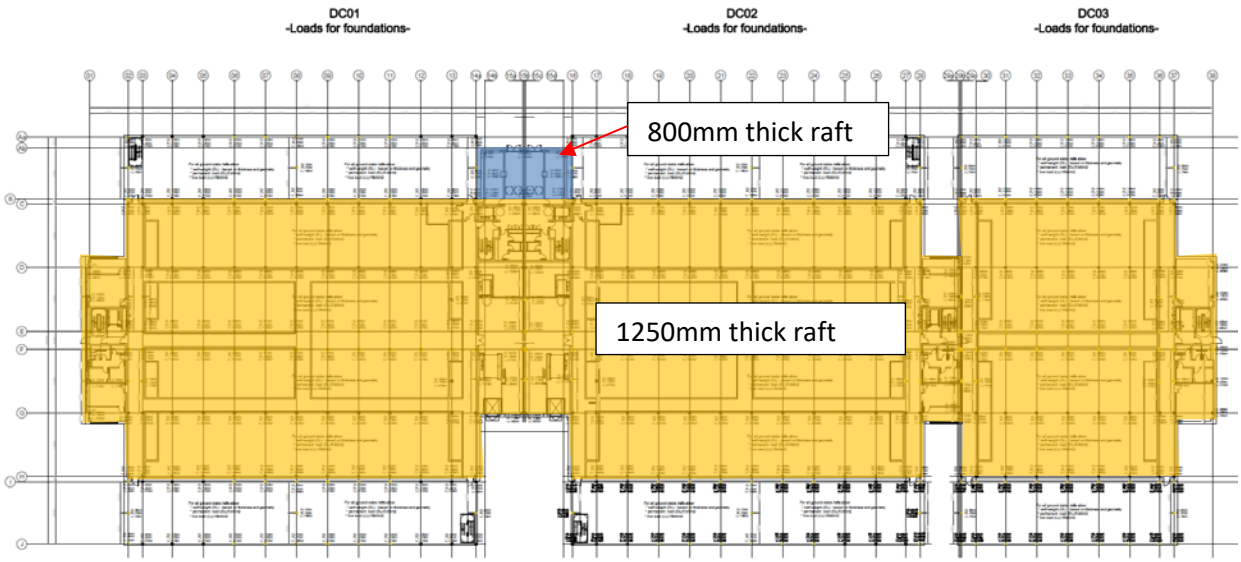
2.2.2 Existing ground levels across the footprint of the proposed data centre is between 54mOD to 50mOD. The proposed building will have a formation level of around 48.25mOD and a finished floor level of around 49.5mOD.

2.2.3 The proposed development plans are included in Appendix 1.

2.3 **Scope of Works**

2.3.1 This report has been undertaken to assess the feasibility of supporting the building on a raft foundation. The assessment has considered a raft measuring circa 50.5m wide and 196.5m long, supporting the central section of the building. A gantry along the two longer sides of the building will be supported on ground beams. The majority of the proposed raft slab is 1250mm thick, with a localised 800mm section as shown in Plate 1.

2.3.2 ***Plate 1. Raft Slab Layout***



3.0 GROUND AND GROUNDWATER CONDITIONS

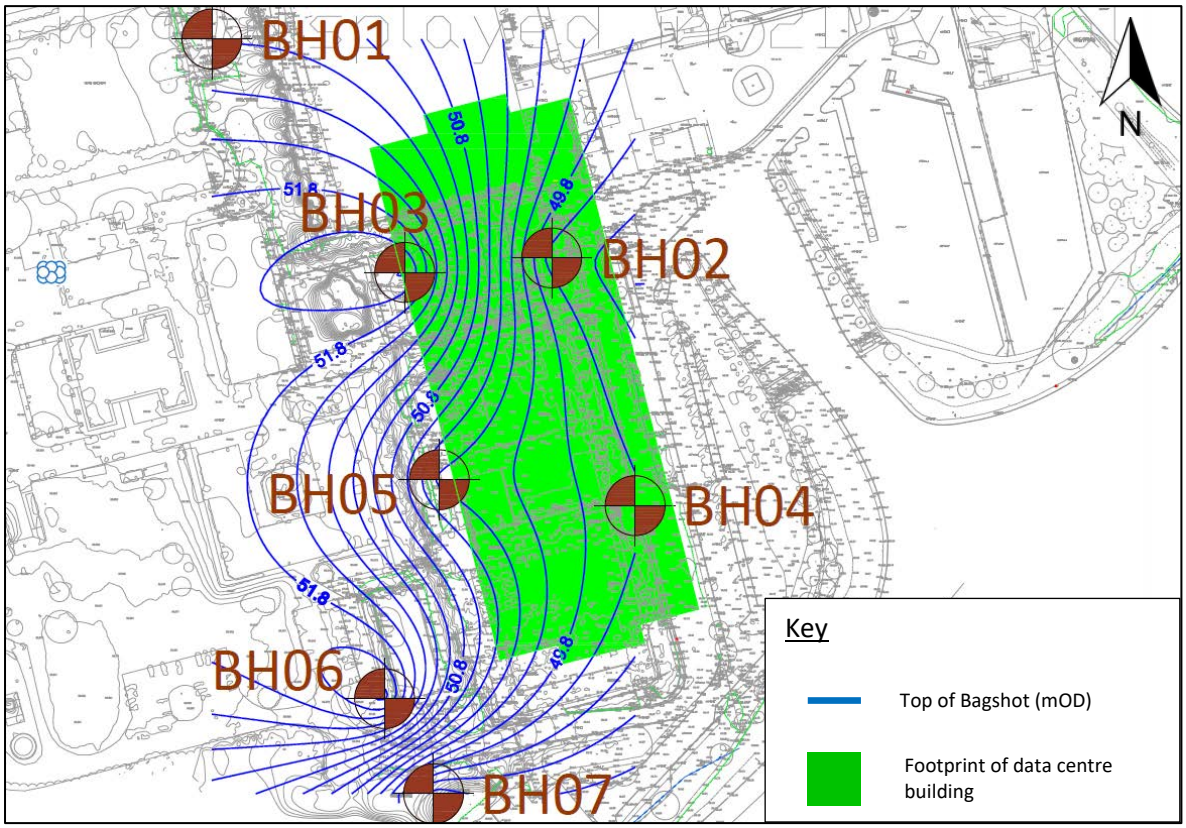
3.1 General

3.1.1 The ground conditions were investigated by Paragon (2020) which included seven sonic boreholes, ten window samples boreholes and thirteen trial pits. The findings of this site investigation are summarised below. The Phase 2 Site Investigation report by Paragon (2020) should be read for further details.

3.2 Summary of Ground Conditions

3.2.1 Ground conditions encountered during the investigation comprised Made Ground, River Terrace Deposits, Windlesham Formation and Bagshot Formation in that sequential order from ground level. The River Terrace Deposits were generally encountered in the southwest of the site at the top of a slope, which runs along the western side of the site. The River Terrace Deposits were also encountered in one borehole located in the north-east of the site. The Windlesham Formation was found to dip towards the northeast across the site, with its thickness increasing from the northern area of the site increasing towards to the south. The Bagshot Formation was encountered across the extent of the site, with the top of the stratum at about 55m above Ordnance Datum (mOD) along the western edge of proposed data centre building and site boundary to approximately 49.5mOD along the eastern edge of the building, as shown in Plate 2. The top 5m of the stratum was found to contain bands of silt.

3.2.2 ***Plate 2. Top of the Bagshot Formation***



3.2.3 The proposed data centre building is located to the east of the slope mentioned above and therefore the thickness of the River Terrace Deposits is anticipated to be very limited below the footprint of the proposed building. As the proposed formation level for the raft will be around 48.25mOD, it is expected the remaining deposits of the River Terrace Deposits and Windlesham Formation will be removed during excavation to formation and raft slab will be formed on the granular Bagshot Formation.

3.3 Summary of Groundwater Conditions

3.3.1 During the three monitoring rounds undertaken by Paragon between 7th July and 22nd July 2020, groundwater was recorded to be generally present in the Bagshot Formation at between 43.44mOD and 44.28mOD. Groundwater was also recorded in one borehole at 48.21mOD during the first monitoring round. During the subsequent monitoring rounds the groundwater was found to drop, with the last round recording the well as being dry. It should be noted that the well had a maximum response depth of 5m below ground level (mbgl) (47.78mOD) and therefore the groundwater may be present below this depth.

3.3.2 For the purpose of this report a design groundwater level of 44mOD has been adopted.

3.4 Geotechnical Design Parameters

3.4.1 The geotechnical design parameters derived from the Phase 2 site investigation report have been adopted in this report and are presented in Table 1 below. The parameters were derived based on the results of in-situ testing and laboratory soil classification tests.

3.4.2 ***Table 1. Geotechnical Design Parameters***

Stratum	Design Level (mbgl) [mOD]	Bulk Weight, γ_b (kN/m^3)	Undrained Cohesion, c_u (kPa) [c']	Angle of friction, φ' (°)	Young's Modulus, E_u (MPa) [E']
Made Ground	Varies [58 to 49]	18	[0]	28[a]	[15]
River Terrace Deposits	Varies [56 to 51]	20	[0]	33[a]	[40]
Windlesham Formation	Varies [55 to 48.5]	20	70 [2]	28[b]	42[c] [33.6][d]
Bagshot Formation (with silt bands)	[51]	20	[0]	35[a]	[50]
Bagshot Formation (without silt bands)	[46]	20	[0]	40[a]	[60 +10z[e]]

a. Peck, R.B., Hanson, W.E., and Thornburn, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.

b. BS 8002:2015 Code of practice for Earth retaining structures, British Standards institution.

c. Based on $600c_u$

d. Based on $0.8E_u$

e. z – Depth below top of stratum

4.0 RAFT SETTLEMENT ANALYSIS

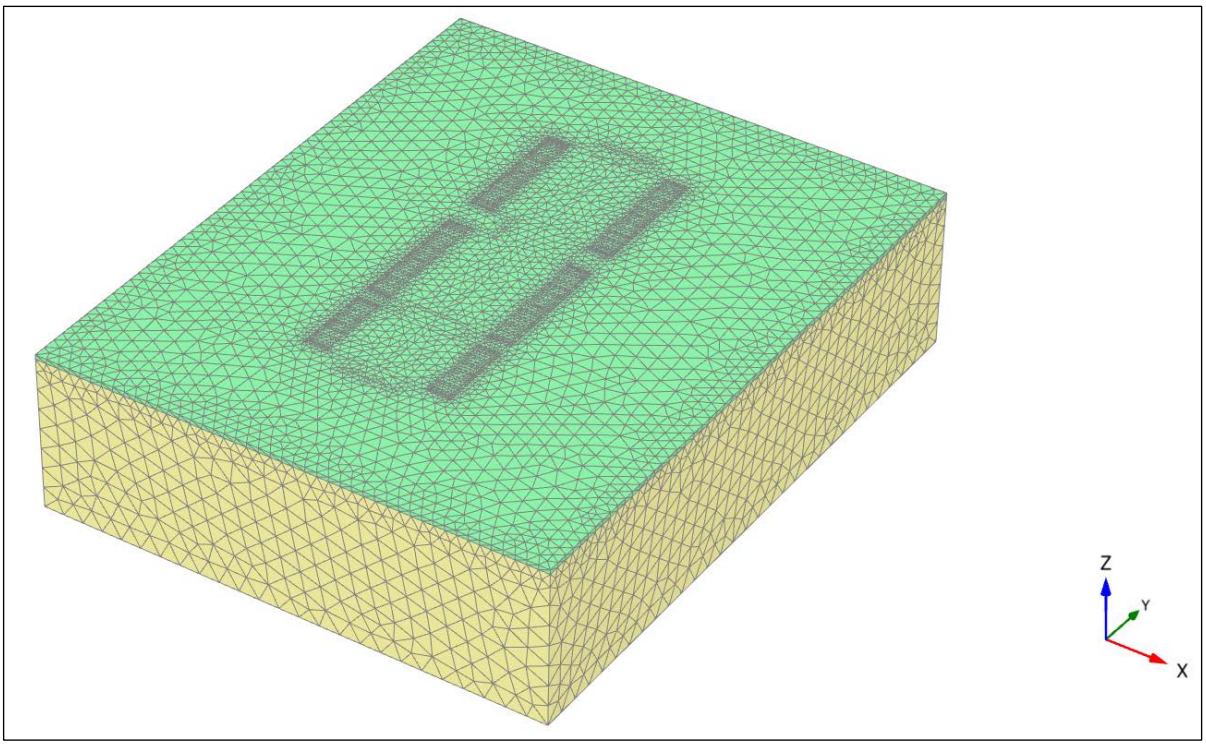
4.1	**General**
4.1.1	An analysis has been carried out using the three-dimensional finite element soil-structure interaction software PLAXIS 3D. The software has been used to calculate the potential settlements of the raft foundation solution.
4.1.2	The model has been solved using the linear elastic constitutive model to analysis the interaction of the raft slab, ground beams, structural loadings and the surrounding soil. The ground conditions in Table 1 have been used in the analysis. A medium mesh with local refinements around structural elements (plates and volumes) has been adopted in the analysis.
4.2	**Loading**
4.2.1	Loads have been provided by the structural engineer and are included in Appendix 2. The loads comprise individual columns bearing onto the raft and external ground beams, and a uniformly distributed surface load applied from the raft slab. The surface load consist of the self-weight of the raft slab (assuming unit weight of 25kN/m3), the permanent loads (shown in Appendix 2 to be 5kN/m2) and the live loads (shown in Appendix 2 to be 15kN/m2). The individual column loads comprise of a combined self-weight, permanent load and live load as shown in Appendix 2.
4.2.2	Given the nature of the soils present below the site (granular with relatively high permeability), it is considered that any heave movement due to stress relief associated with the reduction of levels to reach raft formation will happen immediately upon excavation therefore, the surface of the analysis model has been taken at raft formation level with no net reduction in loading due to excavations considered as a conservative approach. However, the sensitivity of this has been checked and found to have a negligible effect on the predicted settlements.
4.3	**Structural Elements**
4.3.1	The analysis has modelled the ground beams as 1600mm deep by 1200mm and 1500mm wide concrete volumes. The 800mm and 1250mm raft slabs have been modelled as plate elements. Both the plates and the volumes have been assigned a Young's Modulus of 28GPa, a Poisson's ratio of 0.2 and a unit weight of 25kN/m3, representative of the properties of reinforced concrete.

4.4 **Analysis Stages**

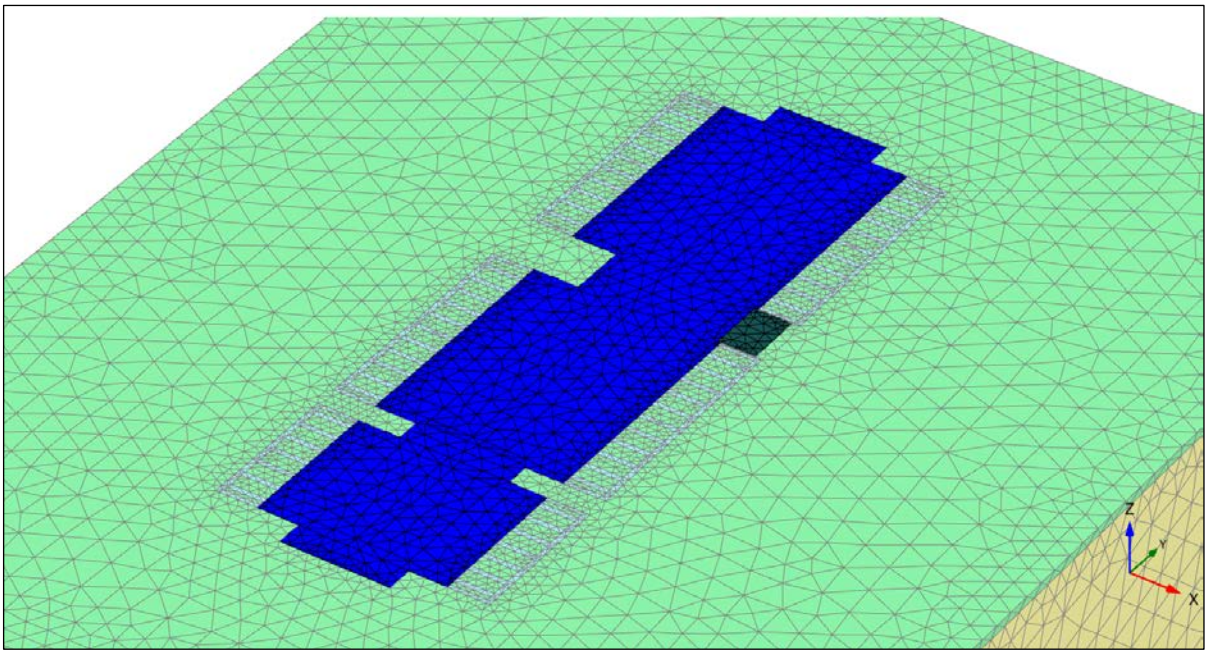
4.4.1 The PLAXIS 3D model has been run in the following sequential stages:

- Stage 1 – Model solved with only the soil and groundwater activated to setup the initial stress conditions (se Plate 3);
- Stage 2 – Activate ground beam volumes and raft slab plate element (see Plate 4);
- Stage 3 – Apply structural loads (see Plate 5).

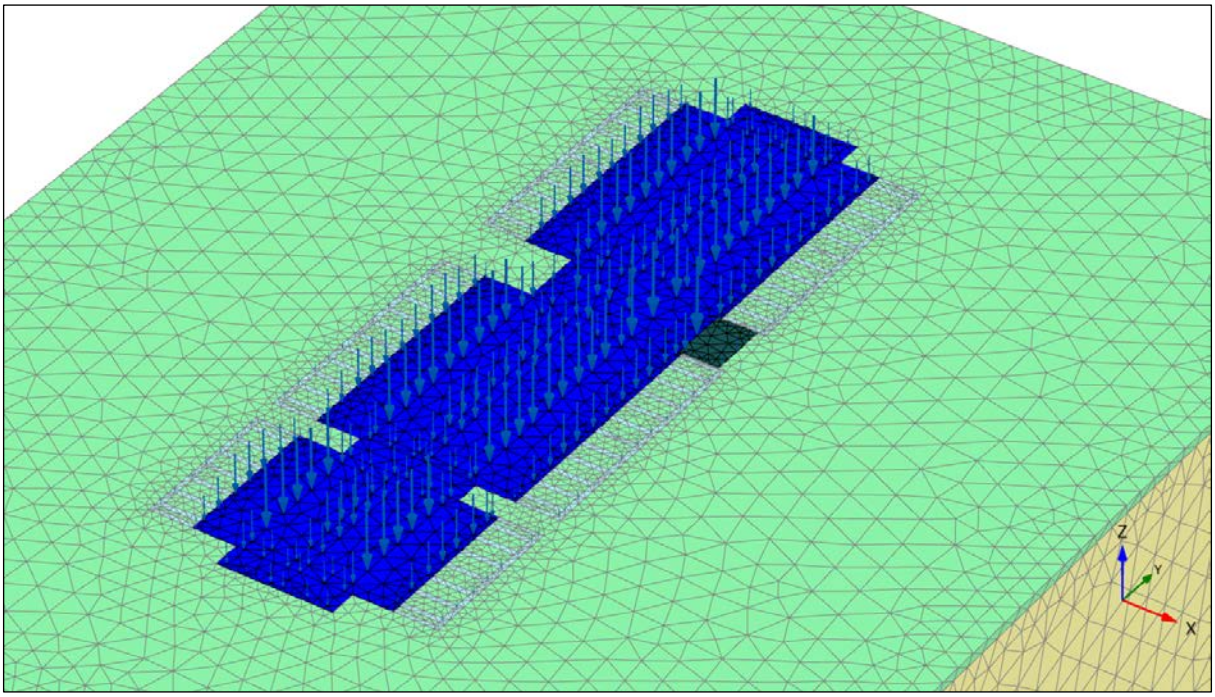
4.4.2 ***Plate 3. Stage 1 (Initial Stage) - Soils and groundwater active***



4.4.3 ***Plate 4. Stage 2 – Construct ground beams and raft slab***



4.4.4 ***Plate 5. Stage 3 – Construction loading applied***



5.0 ANALYSIS RESULTS

5.1 Displacements and Angular Distortions

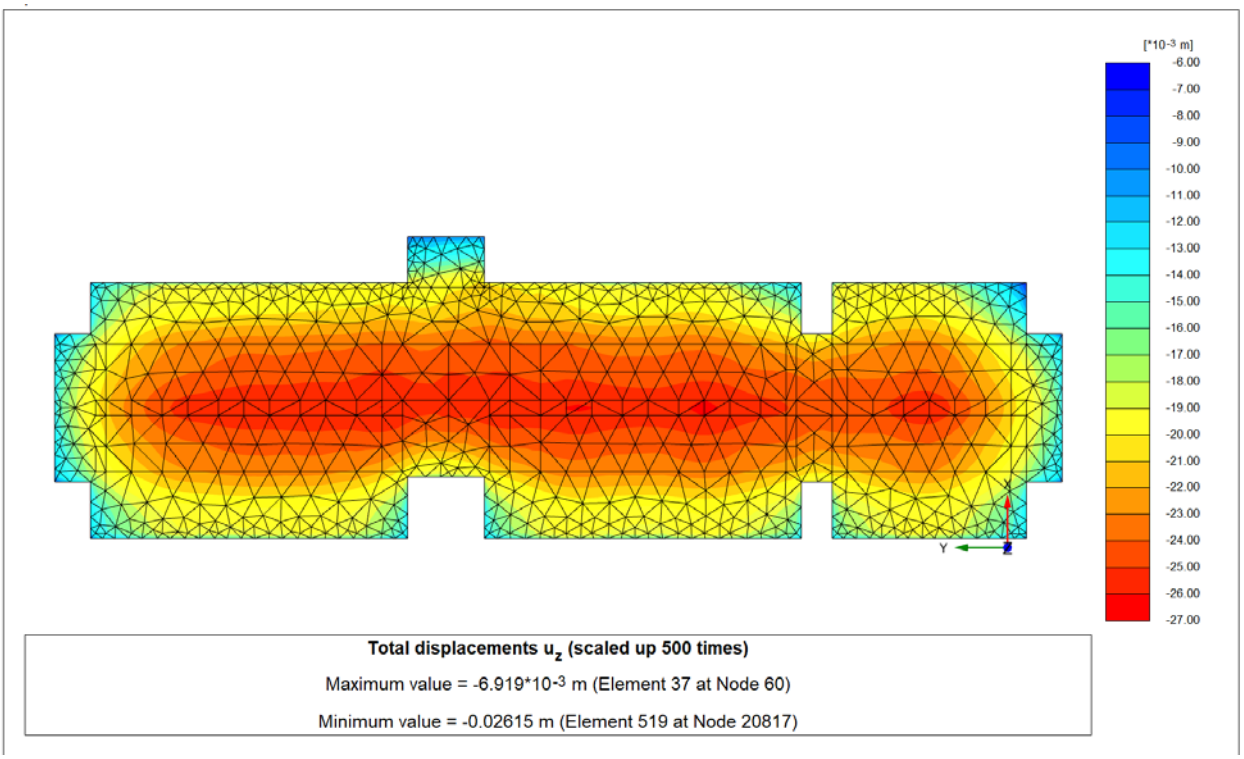
5.1.1 The displacement and worst case angular distortion are summarised in Table 2.

5.1.2 ***Table 2. Summary of predicted settlements and angular distortion***

Minimum Displacement (mm)	Maximum Settlement (mm)	Average Settlement (mm)	Worst Case Angular Distortion
7	26	20	1/980

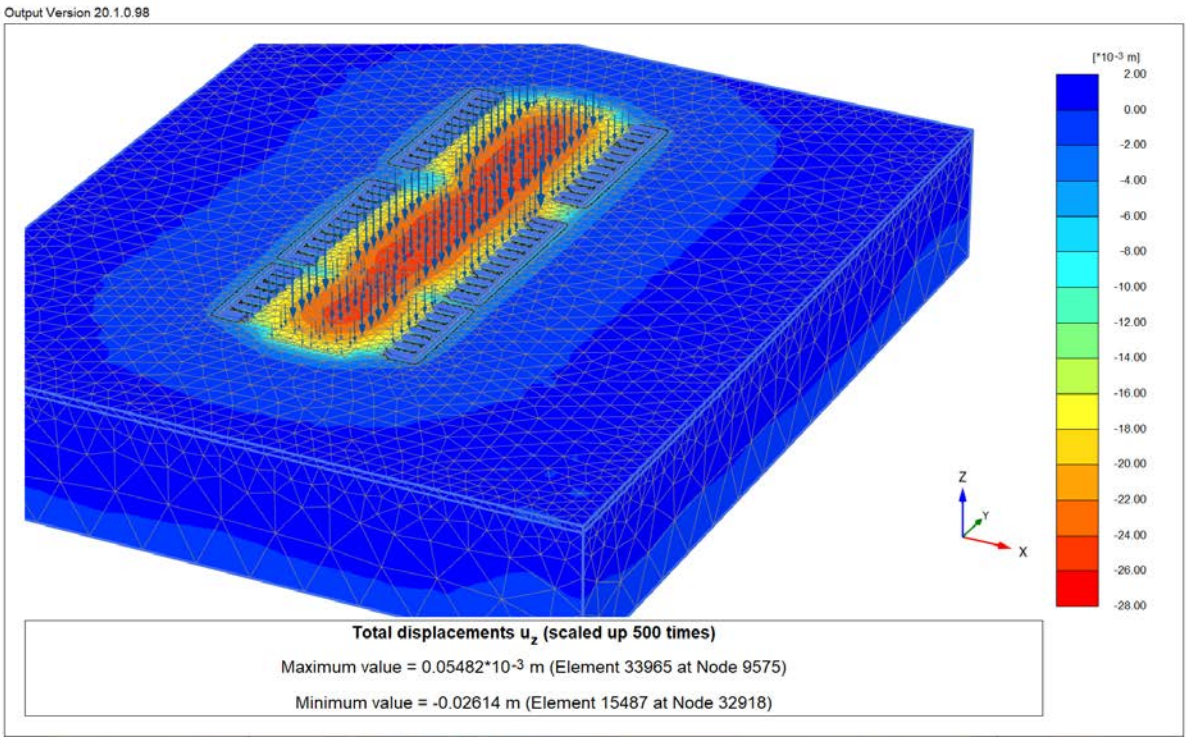
5.1.3 The predicted worst case angular distortion is approximately 1/980. This value is within the limits identified by Skempton and MacDonald[1] for structural damage, where it is stated that the safe limit of angular distortion to prevent structural damage is in the region 1/150 and 1/500 for internal partitions. The displacements at formation level for the raft are presented in Plate 6. Plate 7 shows the surrounding soil settlement profile.

5.1.4 ***Plate 6. Raft settlement at formation level***



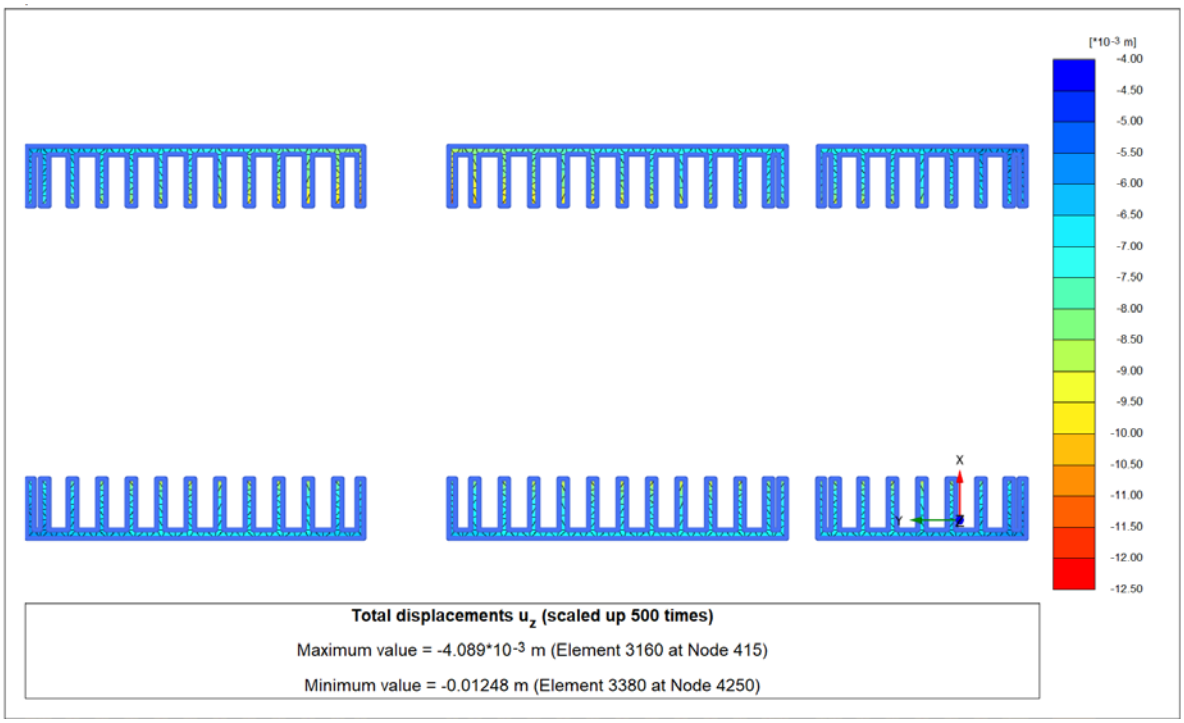
[1] Skempton, A.W. and MacDonald, D.H. (1956). Allowable settlement of buildings. Proceedings of the Institute of Civil Engineers, part 3, vol. 5, pp 727-768.

5.1.5 ***Plate 7. Soil settlement profile***



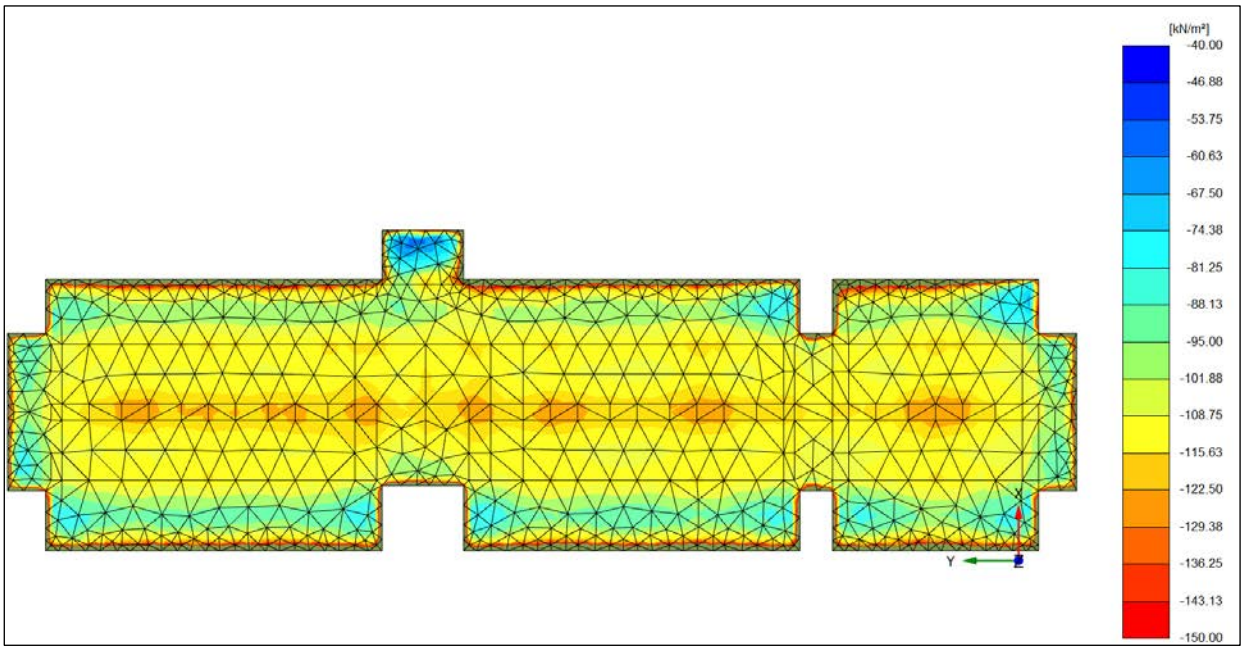
5.1.6 The settlement results for the ground beams are presented in Plate 8. The results show 4mm to 12mm of settlement, with a typical average settlement of 7mm.

5.1.7 ***Plate 8. Ground beam settlement***



5.1.8 The predicted vertical stress in the soil at the underside of the raft slab is presented in Plate 9.

5.1.9 ***Plate 9. Vertical stress in soil at formation level***



5.2 Spring Stiffness

5.2.1 An indicative spring stiffness has been derived from the results of the analysis to inform structural modelling and reinforcement detailing of the raft slab. The spring stiffness presented in Table 3 has been calculated based on the average settlement and average vertical stress across the raft slab. It is noted that this value is indicative only and is likely to require adjustment within the structural analysis model in order to generate a similar magnitude and profile of displacement as predicted in the advanced PLAXIS 3D soil-structural interaction model, and previously shown in Plate 6. The structural engineer should undertake sensitivity analysis and spring stiffness 'zoning' if required in their structural model until the magnitude and profile of movement mimics the geotechnical model, with the indicative spring stiffness value below used as the starting point for the assessment.

5.2.2 ***Table 3. Summary of indicative raft spring stiffness to inform starting point for structural modelling***

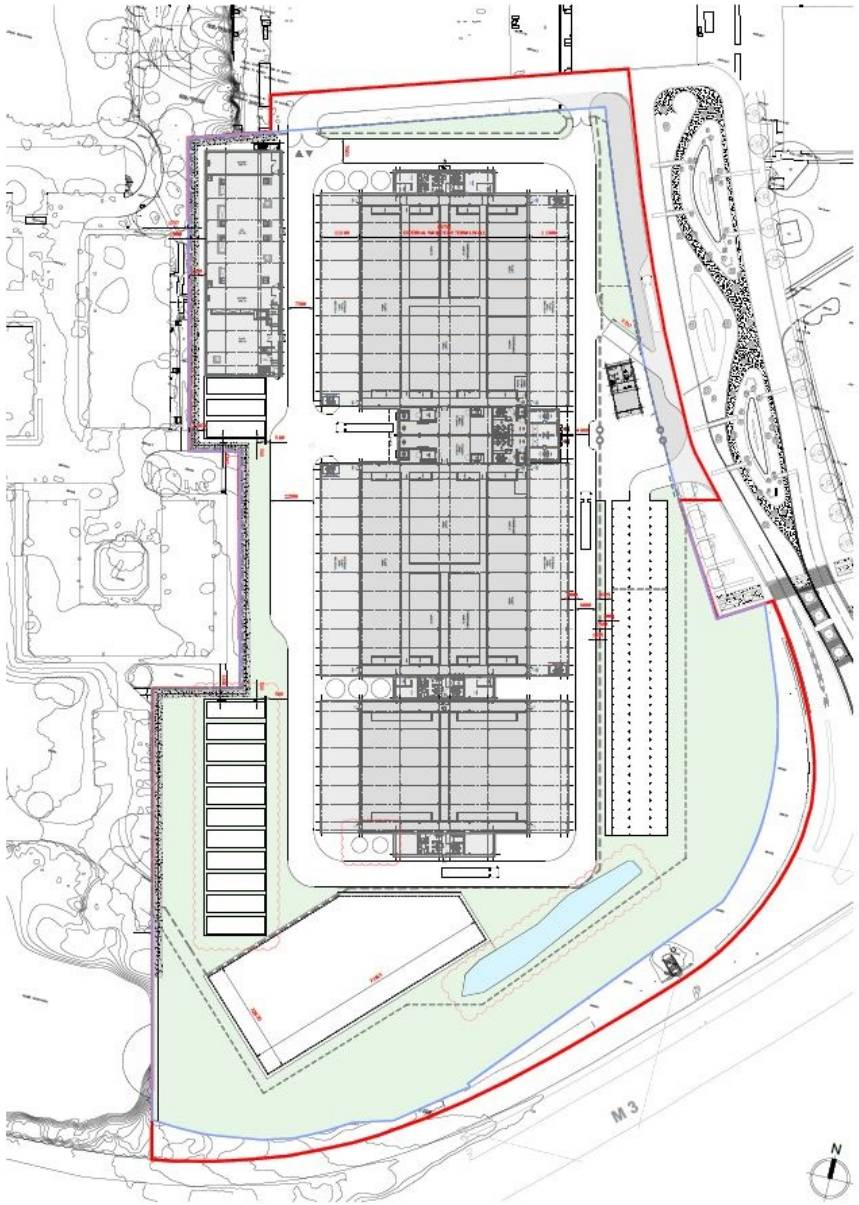
Average Settlement (mm)	Average Vertical Stress (kPa)	Indicative Spring Stiffness (MN/m^3)
20	120	6

6.0 CONCLUSIONS

6.1	**Summary**
6.1.1	An analysis has been carried out to assess the feasibility of a raft foundation solution for the proposed development at Longcross Film Studios. The analysis has been undertaken using the three-dimensional finite element soil-structure-interaction analysis software PLAXIS 3D. The model has been based on the findings of the Phase 2 Site Investigation Report by Paragon (2020) and the SLS loads provided by the structural engineer. The key findings of the assessment are as follows: • Predicted settlements are relatively low for the proposed structure and considered to be within sustainable limits, with an average vertical settlement of 20mm is predicted across the raft; • The maximum angular distortion across the raft is predicted to be 1/980, which is within acceptable limits for the proposed building construction type. • The recommended spring stiffnesses to be adopted initially to supplement structural modelling and detailing of the raft is 6MN/m3 however, this is likely to require adjustments/zoning in the structural model by the structural engineer so that the displacement magnitude and profile mimics that predicted in this assessment by the detailed geotechnical model. • Based on the findings of this assessment it is considered that a raft is a feasible foundation solution for the proposed development.

APPENDIX 1: PROPOSED DEVELOPMENT PLAN

01 Proposed Site Plan



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Notes

Basemap: Hale Architecture, Proposed Site Plan DC01, DC02 and DC03. Reference: 19063-SK6020 rev 1.
Dated: 10/08/2020

Rev	Description	Date

Project
Longcross Studios

Scale N/A

Drawn by CB

Approved By CK

Drawing Title
Proposed Layout Plan

Drawing Number 1

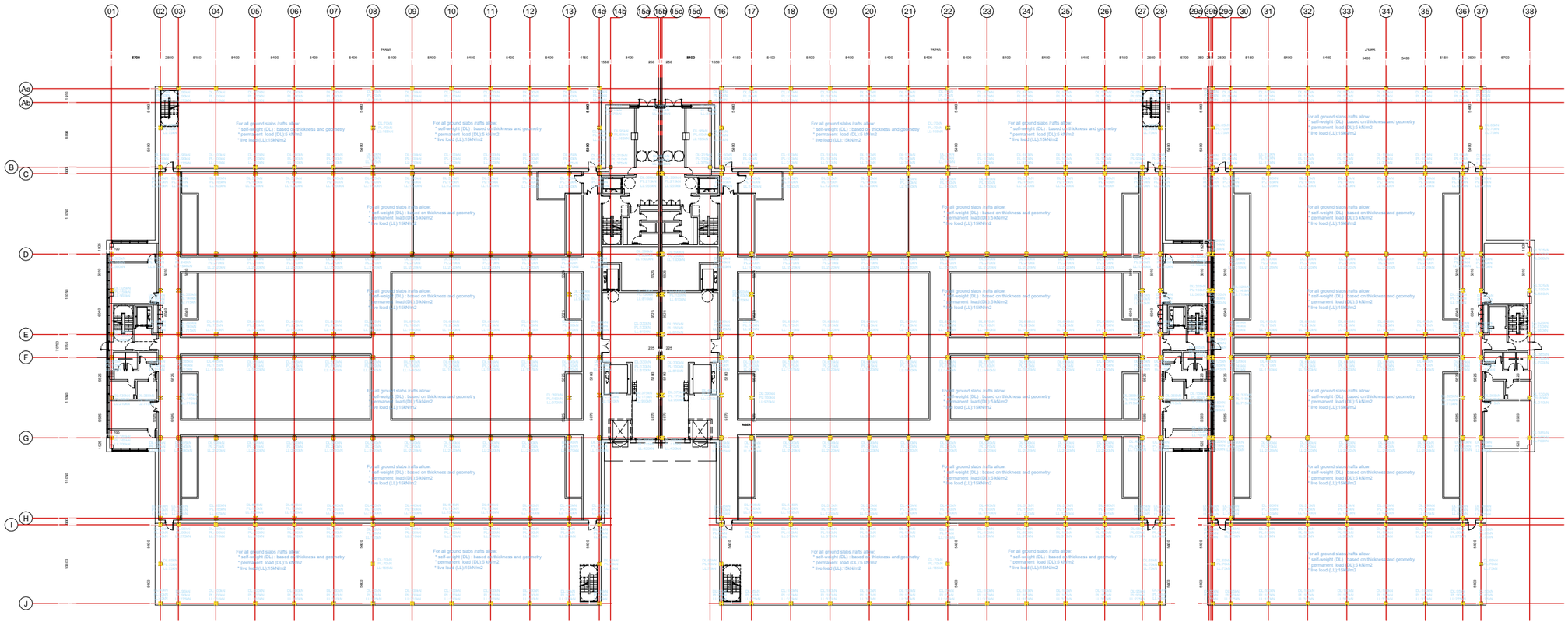
Date 21/10/2020

APPENDIX 2: BUILDING SERVICEABILITY LIMIT STATE (SLS) LOADS

DC01
-Loads for foundations-

DC02
-Loads for foundations-

DC03
-Loads for foundations-



Notes:

Rev.	Description	Date
N/A	N/A	N/A

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Client:
HPF

Project Address:
Longcross Film Studios

Drawing Title:
Proposed Loads

Project Number:	Drawing Number:	Revision:
200567	02	- - -

Drawing Status:
Proposed

Scale:	Date:
NTS	21/10/2020

Drawn By:	Checked By:
CB	CK

APPENDIX 3: EXTENT OF SURVEY AND LIMITATIONS

EXTENT OF SURVEY AND LIMITATIONS

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The report has been designed to address the proposed development, by means of intrusive investigation. The content and findings of the report are based on data obtained by employing site assessment methods and techniques, considered appropriate to the site as far as can be interpreted from desk-based materials and a visual walkover of the site. Such techniques and methods are subject to limitations and constraints set out in the report. The findings and opinions are relevant at the time of writing, and should not be relied upon at a substantially later date as site conditions can changes. For example, seasonal groundwater levels, natural degradation of contaminants etc.

No liability can be accepted for the conditions that have not been revealed by the exploratory hole locations, or those which occur between each location. Whilst every effort will be made to interpolate the conditions between exploratory locations, such information is only indicative and liability cannot be accepted for its accuracy. By their nature, exploratory holes provide a relatively small and localised snapshot of the ground conditions relative to the size of the site.

The opinions given within this report have been dictated by the finite data on which they are based and are relevant only to the purpose for which the report was commissioned. If additional information or data becomes available which may affect the opinions expressed in this report, Paragon reserves the right to review such information and, if warranted, to modify the opinions accordingly. Paragon reserves the right to charge additional fees for; un-anticipated second opinion reviewing of previous reports.

Paragon has prepared this report with reasonable skill, care and diligence. The recommendations contained in this report represent our professional opinions. These opinions were arrived at in accordance with currently accepted industry practices at this time. The work undertaken to provide the basis of this report comprised a study of available documented information from a variety of sources. We cannot provide guarantees or warranties for the accuracy of third-party data, which is reviewed in good faith and assumed to be representative and accurate.

It should be noted that any risks identified in this report are perceived risks based on the information reviewed. No liability can be accepted for the effects of any future changes to such guidelines and site conditions or design changes to the development. In the event that there are changes in this regard, it may be necessary for Paragon to update or modify reports. Changes to site conditions or design may require a reassessment.