



St Modwen Homes

Hendrefoilan, Swansea

Hendrefoilan Phase 2: Supplementary Ground Investigation

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I Introduction

I.1 Overview

PJA have been commissioned by St Modwen Properties Ltd to design and carry out a supplementary ground investigation and prepare a ground conditions report and preliminary foundations appraisal for Phase 2 of the residential redevelopment of the Hendrefoilan site in Swansea.

The wider site was formally used as a Student Village and is currently undergoing a phased redevelopment. Phase 1 lies immediately northeast of the site and covers approximately 3.45 Acres and was completed in 2020.

Phase 2 (the site) covers approximately 4.2 acres. The buildings on the southern part of the site were demolished circa 2017/2018. The remaining site comprises a number of former student accommodation blocks that are currently awaiting demolition.

The site is shown on PJA drawing : Hendrefoilan Site Boundary Plan: 05151-SK-9001-P00,

I.2 Previous work

In 2012 Integral Geotechnique conducted a ground investigation (report reference 11020/GNS/12) and produced a Coal Mining Risk Assessment (letter reference 11020/GNS dated 24/08/2012) to allow a geotechnical and geo environmental appraisal for the site and provide basis for the design.

Integral Geotechnique identified the potential for shallow workings to underlie the site. A copy of the Coal Mining Risk Assessment is presented in Appendix A.

In 2016 Atkins were commissioned to carry out an additional investigation on the potential for coal working and to further characterise the site and assess development considerations to support an outline planning application (report reference 5127544/GEO/RPT/001).

A summary of recorded ground conditions, as identified by Integral Geotechnique and Atkins are provided in Section 2.



I.3 Scope of Report

This report details the findings of the ground investigation carried out in August 2021 to confirm the ground conditions ahead of proposed remodelling earthworks. A foundation zonation plan has also been produced to inform foundation design of phase 2 of the housing development.

Furthermore, the stockpiles of material currently stored onsite has been sampled and tested to characterise it and identify any potential for re use.

Previous ground investigations and reports at the site have been previously submitted to the local authority to support an outline planning application for the development of phases 1 & 2 of the former student village. Planning permission was granted in January 2016 with no conditions relating to land contamination. Therefore this report solely focuses on the ground conditions for the proposed reprofiling earthworks and anticipated building layout.



2 Summary of Previous Desk Study

2.1 General

A Desk Study was carried out and reported by Integral Geotechnique in 2012. This was summarised by Atkins in 2016 for their Ground Conditions report produced in 2016. A brief summary of relevant information for Phase 2 from these reports is provided below.

2.2 Site Location & Current Use

The Hendrefoilan Campus is centred on National Grid Reference (NGR) 261015, 193459 in the city of Swansea. The wider site (Hendrefoilan Student Village) has been partially redeveloped into residential properties (Phase 1) as shown on the PJA drawing : Hendrefoilan Site Boundary Plan: 05151-SK-9001-P00. Phase 2 (hereafter referred to as the site) is mostly located to the south and west of Phase 1. To the north of phases 1 and 2 are student accommodation blocks that remain in use.

The site is an irregular parcel of land, of approximately 1.7 hectares and is accessed off Hendrefoilan Drive. The area comprises 20 residential blocks, a laundrette & bar facility, a convenience shop, and a building used by the university as a reception.

The site is bisected by Hendrefoilan drive that passes through the site, to access the 'active' student accommodation to the north of the site. to the north of Hendrefoilan drive, are former tennis courts in a poor state, beyond them is a mature wooded area with steep and uneven terrain. To the south east of these tennis courts are a number of university buildings including a convenience shop and the university reception building, these buildings are believed to remain in use.

South of Hendrefoilan Drive at the north western end of the site, are a number two story residential blocks which are awaiting demolition. The topography in this area rises steeply to the west. The buildings in this area are vacant and the area is fenced off from the surrounding student village. A number of vacant buildings wrap around a fenced off area that was formally densely vegetated. The layout of the former student residential blocks is shown on PJA drawing: Hendrefoilan Site Boundary Plan: 05151-SK-9001-P00

In the centre of the site, to the south of Hendrefoilan Drive is a student bar and laundrette, this building also remains in use.

To the south east is scrub land of uneven terrain, currently occupied by stockpiles and some discarded house building materials. This area was formally occupied by student accommodation, similar to those seen in the west of the site, but these were demolished around 2017/2018.



2.3 Surrounding land use

To the north of the site, is a number of 2-3 story accommodation blocks still in use as student accommodation. To immediate north west of the site is the completed Phase 1 residential development, comprising a number of two to three story detached and semi-detached properties.

To northwest of the site is a wooded area, giving way to private residential properties which wrap around the site to west and south west. The southern boundary of the site is defined by a 15- 20m strip of mature woodland beyond which are private residential houses. To the south east of the site is an area of woodland which extends to the A4118, approximately 45m to the south east of the site.

2.4 Geology

Information of the geology has been obtained from the BGS online Onshore GeoIndex (<https://mapapps2.bgs.ac.uk/geoindex/home.html>).

The solid geology underlying the site is shown to comprise the Rhondda Member of the Pennant Sandstone Formation. This consists of green/grey sandstones with thin mudstones and siltstones interbedded with thin coals.

A coal seam (Penclawdd coal seam) is shown in the southern part of the site, and with reference to the British Geological Survey (BGS) 1:50,000 scale, Geological Map, Solid and Drift, Sheet 247, Swansea, dated 2011, the strata is indicated to dip towards the north east between 30 and 45 degrees

Glaciofluvial deposits are shown to underlie the north eastern parts of the site and are described as typically comprising sand and gravel.

2.5 Hydrology & Hydrogeology

A small stream, 'Nant yr olchfa' flows from north to south to the east of the site. A number of tributaries feed into this, draining the land to the north. One such drainage ditch flows along the northwest corner of the site.

The BGS online Onshore GeoIndex (<https://mapapps2.bgs.ac.uk/geoindex/home.html>). web-based groundwater vulnerability maps classify both the Glaciofluvial Deposits and the Pennant Sandstone Formation as Secondary 'A' Aquifers. A Secondary 'A' Aquifer is defined as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an



important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

2.6 Site History

The site history is described in previous reports and historical ordinance survey maps are contained in the Integral Geotechnique 2012 report (report reference 11020/GNS/12). A brief summary of the sites history is provided here for completeness.

The 1879 map records the site being undeveloped fields and woodland. To the north of the site, several at this time, with several streams converge flowing into the Nant yr Olchfa which flows to the east of the site.

The 1900 map shows a quarry marked approximately 185m to the north west of the site, and a second quarry approximately 400m to the north

The map dated circa 1921 recorded little change on site the quarries surrounding the site are now marked as 'old', and an 'Air shaft' is shown approximately 250m to the west of the site.

Between 1938 and 1953, the site itself shows little change, the surrounding area has been developed with construction of local infrastructure and expansion of the residential properties predominantly to the south of the site.

The map dated circa 1964- 1975, has partial coverage of the site, but nevertheless it labels the student village as having been constructed. This development continued to the north of the site through the 1980's and into the early 1990's. The residential developments to the west and north west of the site are shown on the maps dated 1993-1997. The layout of the campus or immediate surroundings had not changed significantly since the 1990's.

2.7 Mining

The Integral Geotechnique site investigation report (2012) includes a Coal Authority mining report which stated that the site was in a likely zone of influence from shallow mine workings. The coal authority reported that the property is within an area where coal is at, or close to, the surface and therefore there is a potential risk of shallow mining related ground subsidence.

In 2012 Integral Geotechnique produced a Mining Risk Assessment Letter Report (Appendix A) which included mine abandonment plans.



This letter reported that workings in the Penclawd coal seam, sub cropping near the southern site boundary, were potentially within 30m from the ground surface. The report goes on to say that due to the steep dip of the coal seam (approximately 45 to the north), the zone of influence on the surface from the shallow mine workings is likely to diminish rapidly in a northerly direction.

The coal authority abandonment plans obtained by integral Geotechnique in 2012 indicated that the site is underlain by workings in the Penclawdd and the Rock (at depth) coal seams. The depth of these workings isn't known.

Based on this information integral Geotechnique recommended rotary probe holes should be drilled in the southern part of the site to prove or disprove the presence of any shallow coal seams or abandoned mine workings.

As part of the 2016 Atkins investigation nine rotary holes were drilled to depths of between 30 and 45mbgl to investigate the potential for abandoned mine workings. These rotary holes were positioned along a narrow band in the southern part of the site, based on the conjectured subcrop of the Penclawdd coal seam, and the Rock coal seam. No significant coal seams, voids, broken ground or loss of flush were encountered and Atkins concluded that the coal seams were likely subcrop to the south of the site. It was considered by Atkins that any workings beneath the site are not within influencing depth of the surface and therefore not likely to pose a risk to the proposed development.

A summary of the ground conditions encountered during previous investigations is summarised below.



3 Previous investigations

3.1 Integral Geotechnique 2012

A ground investigation was carried out by Integral Geotechnique on behalf of Swansea University between the 18th and 22nd of June 2012. This investigation covered the site and also land to the north which forms part of the wider student village.

The whole investigation comprised, 25 windowless sample holes, drilled to a maximum depth of 5.36m below ground level. Of these 25 locations, 11 were carried out on the site.

The investigation encountered topsoil (0.1-0.2m) overlying Made Ground to a depth of 2.9m. Made ground was typically found to comprise slightly sandy clays and clayey, silty sandy gravels (re-worked natural material). Isolated areas were found to contain anthropogenic inclusions and were described as soft silty slightly sandy gravelly clay with gravel of sandstone, brick, ash, plastic and rare metal.

Underlying the Made Ground were localised Glacio-fluvial deposits comprising firm to very stiff clays.

Exploratory hole logs are included in Integral Geotechnique's Ground Investigation Report (report reference 11020/GNS/12) .

3.2 Atkins 2016

Ian Farmer Associates (IFA) were sub contracted by Atkins to undertake the ground investigation at the site between March and April 2016. The Factual Report with exploratory hole logs produced by IFA is presented in Appendix C.

Exploratory holes were positioned to generally characterise the site and the adjacent Phase 1 development.

The investigation comprised nine cable percussive boreholes, nine rotary open hole drill holes, ten window sample boreholes six machine excavated trial pits and three road cores. Of these locations, three cable percussive holes, two window sample locations, all trial pits and road cores were outside the site boundary in Phase 1.

Across the site, rotary hole locations were positioned along the southern part of the site, located to investigate the potential for abandoned mine workings. Other locations were positioned to confirm general ground conditions across the site.



Made Ground was encountered in all exploratory locations, and found to be between 0.2 and 2.0m thick. The Made Ground was found to be variable but generally comprising soft to firm sandy gravelly clay, and silty gravelly sand. Made Ground was occasionally described as reworked natural soils.

Glaciofluvial deposits were encountered in 14 locations underlying the Made Ground. These deposits were described as soft to firm orange brown and grey slightly silty to very silty slightly gravelly clay and slightly sandy slightly gravelly clay.

The Pennant Sandstone formation was encountered underlying the Glaciofluvial deposits, at depths typically ranging between 0.4m and 4.4mbgl. is the Pennant Sandstone formation. This was generally found to comprise a weathered zone over a weak to moderately strong sandstone with occasional coal laminations.

In BH108 (located in Phase 1, to the north of the site) and in RH205 (at the eastern end of the site), the Sandstone was encountered significantly deeper than elsewhere during the investigation (11.0m bgl in BH108 and at 12.0mbgl in RH205). Atkins suggested that the greater depth to bedrock at these locations may represent the base of a buried glacial channel feature. Rotary open hole RH216, which was drilled 10m to the south of RH205, encountered bedrock at 2.0m bgl. The sudden change in rockhead between the two positions suggests that the buried glacial channel is steeply sided.

The only coal seam of significant thickness was encountered in RH205. A possible coal seam was encountered in RH205 between 31.0m and 32.0m and a definite coal seam was identified between 32.2m and 33.2m bgl. Additional locations were drilled to the south (RH216) and north west (RH217), to further investigate the coal encountered in RH205. Only a thin coal (0.1m thick) was encountered in RH216 at 14.2m bgl and no coal was encountered within RH217, with the holes drilled to depths of 40mbgl and 35mbgl, respectively. Due to this lack of significant coal seams (or evidence of old mine workings) in any of the drill holes except RH205, Atkins deferred that the coal encountered was not the Penclawdd coal seam, it was conjectured that the Penclawdd seam lies at greater depth beneath the site.

3.2.1 Atkins Engineering Assessment & Recommendations

To investigate the potential for contamination on the site, Atkins scheduled 24 samples for a range of contaminants including: toxic metals, TPH, PAH an asbestos. The results of this testing were screened against relevant Generic Assessment Criteria, and only two exceedances relating to arsenic and lead were identified. Both exceedances were located in Phase 1 which has now been re developed.



Three samples from across the site were identified as containing asbestos. Two of these were located in Phase 1. The third was recorded in WS301, which was located adjacent to a road in the western part of the site (see drawing No 1215/2183/1a in the IFA 2016 Factual report provided in Appendix C). At W301, Chrysotile asbestos fibres were recorded at 1.53%, these were related to insulation board/tiles.

Atkins recommended that in this area, the asbestos should be delineated, and a risk assessment carried out by a specialist asbestos consultant to determine suitable mitigation measures during construction and for the final site use (which may potentially include delineation and clean cover/marker layer in affected area).

Ground Gas monitoring results were compared with guideline values given in CIRIA 665. Atkins concluded that based on the data available the site would be classified as Characteristic Situation 2 (CS2) (based upon modified Wilson and Card methodology described in CIRIA C665).

When assessed in accordance with the Boyle and Witherington Method, 'Situation B (low rise housing development with a clear ventilated 150mm underfloor void)', Atkins determined the site as an 'Amber 1' classification.

Atkins went on to highlight the recommended gas protection measures as follows:

- a. Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 2000g DPM and underfloor venting; Or
- b. Beam and block or pre-cast concrete and 2000g DPM/reinforced gas membrane and underfloor venting.

All joints and penetrations should be sealed for both foundation types

With regards to concrete classification, Atkins reported that, chemical test results indicate that a concrete classification of sulphate class DS-1 and Aggressive Chemical Environment for Concrete (ACEC) class of AC-2z should be used for the design of buried concrete. This classification was made on the basis that the site is classified as 'Brownfield' and that mobile groundwater conditions may be present

Atkins were provided with a proposed building layout for 'Phase 1' and an indicative layout plan for the site. They reported that buildings should be founded on the firm/medium dense weathered Pennant Sandstone Formation or Glaciofluvial Deposits, where present. Where the weathered Pennant Sandstone Formation or Glaciofluvial Deposits are soft or loose, Atkins advised that foundations would need to be extended to firm/medium dense material.



4 2021 Ground Investigation Summary

4.1 Subsidiary Investigation Rationale

PJA were provided with a cut and fill earthwork proposal drawing produced by Hydrock as shown on C16034-C180: Phase 2&3 Preliminary Cut and Fill Assessment. A proposed housing layout and levels plan produced by Hydrock was also provided to PJA as shown on: 161034-SKC100 Rev G. Both of these drawings are presented in Appendix B.

With the development proposals in mind, PJA carried out a review of the ground conditions previously reported and identified areas where further investigation was needed to:

- Fill in gaps in the data caused by obstructions encountered during previous phases of investigation;
- Confirm the anticipated ground conditions with relation to the proposed cut and fill earthworks model (which had been absent for earlier investigations)
- Delineate previously identified anomalies
- Characterise materials currently stockpiled onsite.

4.2 Limitations

The investigation locations were partially constrained by the presence of the vacant residential buildings particularly in the western half of the site. Services to the recently developed phase 1 and occupied student accommodation to the north of the site, also had to be considered when positioning investigation locations.

Construction materials (garage doors, fencing, drainage pipes etc) and stockpiles of material have all been stored/ deposited in the southern part of the site. These obstructions have limited the placement of investigation locations in this area.

As mentioned in section 1.3, following the 2016 Atkins investigation and report, planning permission was granted for the development with no outstanding actions regarding land contamination. As such, apart from some samples taken for classification purposes there was no further investigation of issues related to contamination as part of this investigation.

Ground conditions are interpreted by extrapolating from the investigation grid. Ground and ground water conditions are likely to vary between locations and the depths to competent strata may similarly vary, or locally be absent. The regulators or insuring bodies (e.g. NHBC) may have a different interpretation of the data presented and may require alternative engineering solutions to



those proposed in this document. Early engagement with these bodies is highly recommended. PJA cannot be responsible for changes in engineering design imposed by third party bodies.

4.3 Site Work

Site works were undertaken between the 16th and 27th August 2021 by Quantum Geotechnical who also provided full time site supervision of the works. Part time monitoring oversight was provided by PJA Engineering.

Information on buried utilities was provided by St Modwen. All investigations were cleared of services by Quantum using a CAT and Genny.

Quantum provided UXO clearance supervision, to monitor the excavation of each exploratory hole for the potential for buried UXO to be present. Each hole was scanned and visually observed by their appointed consultant who confirmed the absence of any UXO prior to continuation.

The exploratory holes were set out by the PJA engineer according to the proposed site layout and features to be investigated. As time allowed, additional holes were added to the original specification and their locations were selected by the PJA engineer to provide additional information on areas of concern/interest.

The location of the exploratory holes is shown on IFA drawing 1215/2183/1A The following table summarises the investigation works undertaken:

Table 4-1: Exploratory hole locations

Exploratory technique	No. of locations	Maximum depth	Geotechnical testing
Trial Pits	9	3.2mbgl (TP08)	N/A
Cable Percussion Borehole	4	10m (CBH01) or Rockhead	SPTs at 1m intervals
Rotary Borehole	1	35m	SPTs in top 5m
Windowless Sample Borehole	10	4.0m (WS01)	N/A

Borehole and Trial Pit logs are included in Appendix D.

4.3.1 Sampling and laboratory testing

Geotechnical and Geo Environmental laboratory testing was scheduled by PJA on selected samples. Geotechnical testing was carried out on samples from the distinct units within the superficial deposits and included moisture content, Atterberg limits, compaction, and particle size distribution.



Geo Environmental laboratory testing was scheduled by PJA on selected samples of Topsoil, Made Ground, and the superficial deposits. Tests included pH, metals, total petroleum hydrocarbons (TPH), inorganics, and polycyclic aromatic hydrocarbons (PAH).

Table 4-2: Geotechnical Laboratory Testing

Test	No.	Locations	Strata	Stockpile
Moisture Content	17	CP01, CP02 (2), CP03 (3), TP06, TP07 (2), TP09 (2) TP11 (2)	CP01: Clay x 1 CP02: Clay x1, Gravel x1 CP03: Clay x2, Gravel x1 TP06: Gravel x1 TP07: Clay x1, Gravel x1 TP09: Clay x1, Gravel x1 TP11: Clay x1, Gravel x 1	SP1, SP2, SP6, SP8
Atterberg Testing	8	CP01, CP02, CP03 (2) TP07, TP09, TP11	CP01: Clay x 1 CP02: Clay x1, CP03: Clay x2 TP07: Clay x1, TP09: Clay x1, TP11: Clay x1,	SP6
Particle size distribution	17	CP01, CP02 (2), CP03 (3) TP06, TP02 (2), TP09 (2) TP11 (2)	CP01: Clay x 1 CP02: Clay x1, Gravel x1 CP03: Clay x2, Gravel x1 TP06: Gravel x1 TP07: Clay x1, Gravel x1 TP09: Clay x1, Gravel x1 TP11: Clay x1, Gravel x 1	SP1, SP2, SP6, SP8
Consolidation	1	CP01	CP01: Clay x1	N/A
2.5kg Compaction Testing	15	CP02 (2), CP03 (3) TP07 (2), TP09 (2) TP11 (2)	CP02: Clay x1, Gravel x1 CP03: Clay x2, Gravel x1 TP07: Clay x1, Gravel x1 TP09: Clay x1, Gravel x1 TP11: Clay x1, Gravel x 1	SP1, SP2, SP6, SP8

Table 4-3: Geo Environmental Laboratory Testing

Test	No.	Location		Stockpile
General Suite	14	CBH03, CBH04 TPH01, TPH6, TPH9, TPH10, TPH11, TPH12 RH01	TP01: Made Ground TP06: Gravel TP09: Clay TP10: Gravel TP11:Clay TPH12: Made Ground CBH03: Clay CBH04: Gravel	SP1, SP2, SP5, SP6, SP8
BS Topsoil Suite	1	RH01		N/A



5 Site Specific Ground Conditions

5.1 Topsoil

Topsoil was encountered in 16 out of 25 locations across the site and was recorded to be between 0.1 and 2m thick with an average thickness of 0.4m. It was generally described as a brown sandy silt with roots and rootlets.

5.2 Made Ground

Made Ground was encountered in 11 out of the 25 locations. It was encountered between 0 and 0.4mbgl with a recorded thickness ranging between 0.2 and 2.8m and an average thickness of 0.8m.

Made Ground was recorded to be thickest (<2.8m) in TP01 in the north of the site. In this location, the base of the Made Ground was un confirmed as the trial pit was terminated at 2.8m due to the trial pit collapsing.

In the south east corner of the site the depth of made ground was not proved within TP 12 due to the presence of services at circa 2m below existing ground level.

Made Ground was generally described as sandy clayey gravel with cobbles and boulders. Local anthropogenic inclusions consisted of fragments of brick, concrete, plastic, timber glass and metal.

Note: some residual service lines were encountered within TP12. It is not known if these were currently live.

5.3 Superficial Deposits

Two types of glaciofluvial deposits were recorded, a light brown sandy clay and a light brown sandy clayey gravel.

5.3.1 Cohesive deposits

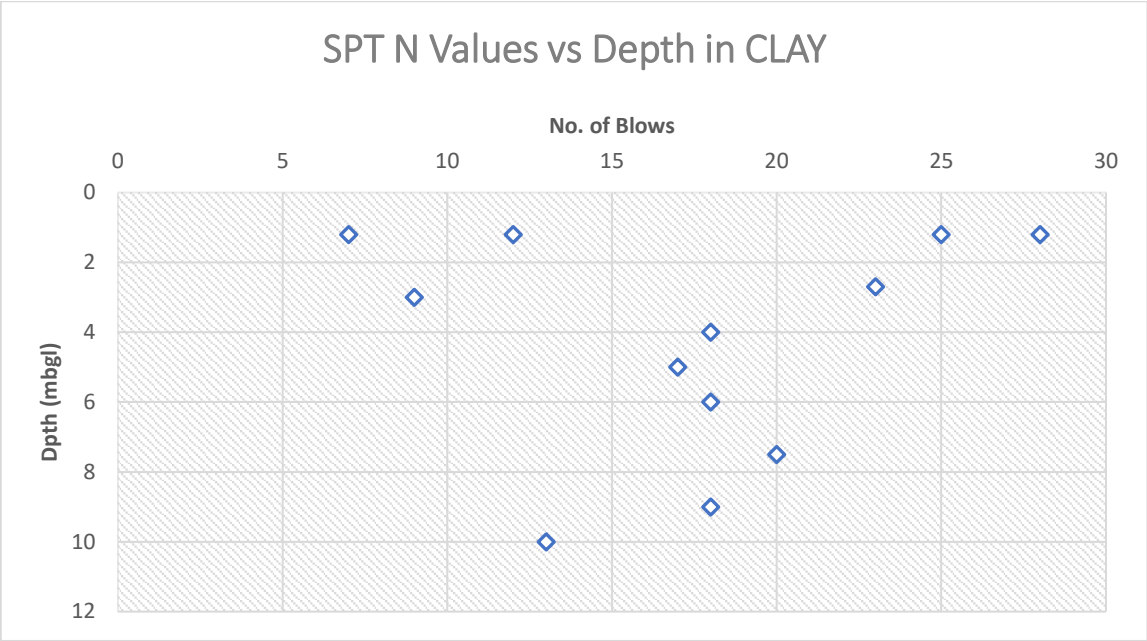
Cohesive deposits were recorded in 11 out of the 25 locations, the top of this unit was recorded at depths ranging between 0.1m and 2mbgl. Where it was recorded, the thickness was recorded between 0.4 in WS04 and 9.8m in CBH01. CBH01 was positioned in the wooded in the north of the site. it was terminated at 10m in the clay.

Cohesive deposits were described as soft to firm to stiff, light brown to grey, sandy gravelly CLAY with cobbles. Gravels and cobbles were recorded as sub angular to sub rounded sandstone.

In Situ Testing



12 No. SPT tests were carried out in the clay deposits. SPT N values ranged between 7 (indicative of firm consistency) and 28 (indicative of very stiff consistency). The graph below plots the SPT N values vs depth for the SPT tests carried out in the cohesive deposits.



Laboratory Testing

Laboratory testing is provided in Appendix C. Seven samples taken from the cohesive deposits were described as a sandy gravelly CLAY with between 19 and 43% of particles <0.063mm with an average of 27%.

Atterberg testing was carried out on samples from the cohesive deposits. The plasticity Index (Ip) from these 7 seven samples ranged from 11 to 25 with an average Ip of 17.8. The modified plasticity index (I'p) Defined as, the Ip multiplied by the percentage of particles less than 0.425mm, has been determined to be between 4.6 and 10, with an average I'p of 7.3.

The Liquid Limit (L) for these samples ranged between 38 and 44% with an average of 41%.

These results suggest the material as an intermediate plasticity clay. The Modified Plasticity index suggests the material has a Low volume change potential.

PSD testing on six out of seven of the samples have classified the majority of the cohesive materials as a Dry Stony Cohesive Material (2C) material in accordance with the requirements of Series 600



in the Specification for highway works. The Sample from CBH01 has been classified as 2A, a dry cohesive material.

Moisture content testing on the seven samples found the natural moisture content ranged from 13- 20%, with an average of 14%. Compaction testing carried out on the material identified the optimum moisture content for this material to be between 9.4 and 15%.

5.3.2 Granular deposits

Deposits which were considered in the field to exhibit more granular behaviour were recorded in 18 out of the 25 locations, the top of this unit was recorded at depths ranging between 0.1m and 2.3mbgl. Where it was recorded, the thickness was recorded between 0.6 in WS06 and 2.6m in TP06.

The unit was described as light to dark brown, grey, sandy clayey gravel with cobbles. The gravel was described as fine to coarse, sub angular to sub rounded sandstone and siltstone.

In Situ Testing

With the exception of one test, all SPTs performed in the sand & gravel unit refused at 50 blows. The one exception was CBH03 at 3m where 49 blows was recorded. Based on the SPT results, the sands and gravels as classified as 'dense' to 'very dense'.

Laboratory Testing

The laboratory testing from this unit indicated a cohesive fraction which suggested a non granular classification despite its field behaviour. Six samples from the sandy clayey gravel were scheduled for PSD testing. Based on the results of this testing five samples have been classified as a Dry Stony Cohesive Material (2C) in accordance with the Series 600 Specification for Highway works. These samples were found to contain between 13 and 25% of particles <0.063mm with an average of 18.75%.

One sample from CBH03 at 2.5mbgl has been classified as a dry cohesive material (2A).

There was no Atterberg testing carried out on this material. The Natural Moisture content of this material was between 5.4 and 17% with an average of 11%. Compaction testing carried out on the material identified the optimum moisture content for this material to be between 6.4 and 15% with an average of 11%.



5.4 Bedrock

Bedrock was confirmed in 10 of the 25 locations, where bedrock was recorded at depths ranging between 1.8 and 3.5mbgl. Rockhead was likely the cause of refusal and terminations in some windowless sampler locations.

The cable percussive boreholes (CB02-CB04) recorded a 0.2m weathered band of sandstone recovered as silty sandy gravel before these locations were terminated on solid bedrock. This weathered horizon was recorded between 0.1 and 0.2m thick in Trial pits TP06-TP11.

Approximately 25m of rock core were recovered from RH01 in the western corner of the site.

Competent bedrock was recorded at 4.2mbgl, and was overlain by 0.7m of sand and gravel which was poorly recovered in the core. This is believed to represent the boundary between the granular superficial deposits and the weather bedrock profile.

The competent bedrock (from 4.2mbgl) was generally recorded as a Greyish brown, slightly to medium weathered, medium grained sandstone.

Between 5.7 and 6.7mbgl was a highly weathered section which was recovered as sub angular sandstone cobbles.

Between 6.7 and 10.2 the recovered core was recorded as a Grey medium weathered medium grained sandstone. Sandstone and Mudstone bands (driller description) were recorded during open hole drilling from 10.2m to 35mbgl. No coal seams or voids were encountered during the drilling.

During the Atkins 2016 investigations, rotary hole location RH205 and RH216 had recorded sandstone at 12.5m and 2m bgl respectively. The window sampler (WS9 & WS10) were positioned by PJA during the recent investigation near to Plot 67 to confirm the depth to rockhead under this plot. The window sampler locations recorded refusal at 1.9 and 2.0mbgl (plausibly on dense granular deposits or bedrock).

Note: the boundary between the superficial and bedrock is likely to be indistinct in many locations. Cobbles, some sub-rounded, may indicate a superficial origin increasing in quantity and angularity with depth. Similarly, the overall engineering behaviour is likely to vary depending on the relative proportion of cobbles and granular and cohesive matrix.

5.5 Groundwater

Ground water was only recorded in two of the 25 locations, in CBH01 at 1.3mbgl and in RH01 at 5.0mbgl.



There were no observations of groundwater in trial pit or window sample exploratory holes

5.6 GeoEnvironmental Testing

GeoEnvironmental characterisation of the site was carried out by Atkins in 2016 associated with planning requirements, a summary of the Atkins findings is provided in section 3.2.1.

A full GeoEnvironmental characterisation of the site is therefore outside the scope of this supplementary ground investigation. However some geo environmental testing has been carried out to provide additional information to future ground workers and to guide the potential reuse of excavated material.

Eight samples were taken from exploratory locations (BH03, BH04, TP01, TP09, TP10, TP11, TP12 and RH01) and scheduled to test for a number of potential contaminants including, toxic metals, TPH, PAH and Asbestos. Details on the sample locations and material type is presented in Table 5-1.

The results of the Geo-environmental testing has been screened against Generic Assessment Criteria for a residential end use with plant uptake. (S4UL's) and are presented in Appendix F.

Table 5-1: Summary of Geo Environmental Testing

Location ID	Depth	Material Type	Testing	Result Summary
BH03	1.0	Sandy gravelly CLAY	Asbestos, Arsenic, Cadmium, Chromium, Magnesium, Copper, Mercury, Nickel, Lead, Selenium, Vanadium, Zinc, Chromium (IV), TPH, PAH	No Exceedances
BH04	1.0	Clayey sandy GRAVEL		Slightly Elevated Arsenic Concentration (39 mg/kg)
TP01	1	Made Ground		Elevated Lead concentration (780 mg/kg)
TP09	0.5	Sandy gravelly CLAY		No Exceedances
TP10	2.0	Silty sandy GRAVEL		No Exceedances
TP11	0.3	Sandy gravelly CLAY		No Exceedances
TP12	0.3	Made Ground		No Exceedances
RH01	0.3	Topsoil	As above + BS Topsoil Suite	No Exceedances, Does not meet specification for BS standard Multipurpose topsoil

From the eight samples tested two were found to contain elevated contaminants in excess of their respective GAC. These samples came from BH04 at 1.0mbgl, and from TP01 at 1.0mbgl.



The sample from BH04 was taken from slightly clayey sandy gravel and was found to contain a marginal exceedance of Arsenic where 39mg/kg was detected compared the GAC for Arsenic of 37 mg/kg.

The Sample from TP01 was taken from Made Ground and the concentration of lead was reported to be 780mg/kg compared to the GAC of 200mg/kg.

The Sample from RH01 was also scheduled for BS Topsoil testing in accordance with BS3882:2015. The material failed to meet the textural class requirements for multipurpose topsoil, furthermore, the results show the material lacks the plant nutrient contents (Nitrogen, potassium & magnesium) to meet the topsoil requirements stated in BS 3882:2015.

The results of all testing are included in the Quantum Factual Report Presented in Appendix D.

5.7 Stockpiles

During the ground investigation PJA carried out an audit on the stockpiles in the south east part of the site. Eight stockpiles have been recorded, with volumes estimated to range from between 10m³ and 500m². PJA have estimated there is between 800 and 1000m³ of total stockpiled material on this part of the site.

The table below summarises the stockpiled material. The volumes of the stockpiles are estimates only.

Stockpile Ref.	Description	Estimated Size (M ³)	Testing	Comments
1	Lightly vegetated stockpile of Sandy gravel with cobbles. Comprising concrete and red brick, rebar, plastic and tarmac. 1A	50	Yes	Presumed to be demolition crush produced during earlier phases of redevelopment.
2	Moderately to well vegetated stockpile of sandy gravel with cobbles and some boulders. Comprising concrete and red	500	Yes	Presumed to be demolition crush produced during earlier



	brick, rebar tarmac fragments and sandstone. 1A			phases of redevelopment.
3	Washed coarse Mudstone gravel chippings	<10 (combined)	No	Likely excess from construction in Phase 1.
4	Bitumen bound fine gravel chippings (black top)		No	Likely excess from construction in Phase 1.
5	Small mound of brown clayey gravelly sand. Comprising fragments of concrete, brick, mudstone and sandstone and occasional plastic.	50	No	Likely excess material from construction in Phase 1.
6	Heavily vegetated brown clayey gravelly sand. Comprising fragments of concrete, brick, and occasional plastic. 1A	150	yes	Material is broadly landscaped with surroundings.
7	Lightly vegetated brown clayey gravelly sand. Comprising fragments of concrete, brick, mudstone and sandstone and occasional plastic.	20	No	Small pile presumed to be excess material from Phase 1.
8	Moderately to well vegetated stockpile of sandy gravel with cobbles and some boulders. Comprising concrete and red brick, plastic and timber fragments 2C	100	yes	Presumed to be demolition crush produced during earlier phases of redevelopment.



Samples were taken from the largest stockpiles, Stockpiles 1, 2 6 & 8. All samples were scheduled for geotechnical and contaminant testing.

Results from the PSD testing of samples have been used to classify the material from stockpiles 1, 2 and 6 as a well graded granular fill (1A). Stockpile 8, has been classified as a stoney cohesive material (2C) in accordance with the Series 600 Specification for Highway works.

The samples taken from the stockpiles were scheduled for chemical testing for the following contaminants: Asbestos, Toxic Metals, TPH & PAH. With no defined use for these materials, the results have been compared with Generic Assessment Criteria for a residential end use with plant uptake. (S4UL's).

The sample taken from Stockpile 1 was found to contain Asbestos Board containing Chrysotile at 0.014%. This sample was also found to contain elevated concentrations of Arsenic, TPH C21-35, Benzo (b) fluoranthene and Dibenz (a,h) Anthracene all above their respective GAC.

The table below shows the reported value for the elevated contaminants in stockpile 1 against their respective GAC.

Contaminant	Concentration reported in sample from Stockpile 1	Suitable 4 Use Level (S4UL) Residential end use with plant uptake.
Arsenic	52	37
Aromatic TPH >C21-C35	1600	1500
Benzo[b]fluoranthene	3.5	3.3
Dibenz(a,h)Anthracene	0.44	0.28

There were no exceedances of the GAC in any other stockpile tested.



6 Engineering Assessment

6.1 General

The site is intended to be developed for a proposed residential end use. The proposed ground remodelling earthworks show areas of cut and fill to create level development areas for individual plots while maintaining the change in topography across the wider site. These proposals are shown on Hydrock drawing: C16034-C180: Phase 2&3 Preliminary Cut & Fill Assessment in Appendix B.

As part of these earthworks, it has been estimated that circa 14,000m³ of material will need to be removed to create the development formation profile.

A preliminary housing layout shown on Hydrock drawing: 161034-SKC100 Rev G in Appendix B. This shows the proposed layout and levels of 108 residential properties and associated surface infrastructure.

The two proposal drawings (earthworks and development layout) have been assessed together along with the information from ground investigation to provide foundation solutions for the proposed development

The following preliminary recommendations are based on the information available from the exploratory holes undertaken on the site (appendices C & D) and are made for a proposed residential end use. The recommendations assume the proposed buildings may comprise typical 2 storey houses with associated infrastructure.

The design and depth of foundations will be dependent upon the proposed foundation loads and the ground conditions present. No detailed information is currently available for the proposed foundation loadings or final site levels. Therefore, only an indicative assessment of the geotechnical characteristics of the ground can be made based on a 'typical' domestic house type.

It is understood the layouts presented are provisional and will need to be confirmed. A revision of the foundations appraisal is required if layout, levels and the extent of cut and fill change.

6.2 Coal Mining

During the 2016 investigation Atkins recorded a lack of coal seams, voids, broken ground or loss of flush in any of their rotary hole locations. They concluded that the Penclawd coal seam shown on BGS maps as outcropping along the southern boundary of the site, was likely to be further south than is conjectured on geological maps. Atkins considered that any workings beneath the site are



not within influencing depth of the surface and do not likely to pose a risk to the proposed development.

The rotary hole drilled as part of this recent investigation was positioned north of the Atkins boreholes, to confirm the Atkins conclusions. This rotary hole location recorded no coal seams, voids or loss of fluid and it is therefore believed that the Penclawd seam does sub crop further south that is shown on the BGS maps.

6.3 Foundations

Table X-1 rev 2, provided in Appendix E lists plot specific anticipated founding strata following the re-profiling earthworks.

Depending on the depth to the anticipated founding strata after the proposed earthworks, an indicative foundation type has been proposed. The anticipated founding strata and plot layout is presented on the Foundation Zoning Plans: 05151-SK-9002, 9003 and 9004-Rev01.

The assessment below does not take specific account of a programme or detailed costings analysis. The optimal mix of solution may therefore alter depending on non-engineering factors. The assessment also assumes that ground levels are as indicated by the Hydrock engineering assessment at the point where foundations are constructed. Where non-standard construction methods are proposed alternative foundation options may be considered but will need to be assessed on a case by case basis.

Foundations are currently anticipated to comprise:

- Traditional Strip (circa 71 plots) – typical depth between 0.75 and 1.5m
- Trench Fill extension (circa 21 plots) – 1.5m to 2.5m
- Ground Improvement (vibro)/ Piles (17 plots) – founding depth circa 3-4m

Many units are proposed to be of split level construction. **For these plots the FFL for the lower segment is taken as the plot formation across the whole plot and against which the foundation assessment is made.** The structural design of these units will need to be confirmed to ensure the founding solution is suitable.

All foundations proposed will need to be confirmed with the insuring body (e.g. NHBC) who may require additional information or may require a different foundation solution or structural support for any particular foundation system, including additional reinforcement.



The third party drawings, provided in Appendix B (C16034-C180, and 161034-SKC100 Rev G), have been used to determine the proposed level and founding strata for each plot. A revision of the indicative foundation proposals is required should the plot layout and proposed ground levels change.

The estimated founding strata is based on the extrapolated data gathered from investigation locations. As such, the location of the interfaces between the different anticipated founding strata must be confirmed on site during foundation excavations. Therefore the foundation type for those plots straddling a change in the founding strata may change depending on the ground conditions encountered during construction.

6.3.1 Shallow Strip foundations

Shallow strip foundations are anticipated to be suitable for plots founded on the bedrock or on medium dense to dense sands and gravels strata (71 plots). Note: laboratory classifications of this material indicated a more cohesive fraction, however, in the field indicated granular behaviour and the strata is described as such in this section to aid identification during construction. Performance may also be influenced by the variable cobble content noted, especially on the superficial/Made Ground interface. It is plausible that this strata varies and the supervising engineer should assess variability as the foundation excavations proceed.

The plots anticipated to be founded with shallow strip foundations on the bedrock or sands and gravels is shown on PJA Foundation Zoning Plan drawings shaded pink. Footings on the Bedrock should be cut a minimum of 450mm into the founding strata to avoid damage from frost action.

Based on the laboratory testing the deposits described as granular in the field have been shown to contain a proportion of fines, classifying the material as a borderline granular/cohesive material. The more cohesive materials on site have been found to have a low volume change potential; this material property has been extrapolated for the more granular materials.

Unless agreed separately with the NHBC, footings in the superficial deposits should be cut a minimum of 750mm (outside the zone of influence of trees/shrubs) into the founding strata to protect against potential volume changes caused by the cohesive properties of the material. Foundations within the zone of influence of trees/shrubs will need to be taken deeper to align with that the minimum depth and width criteria as per NHBC guidance chapter 4.2.7 Building near trees.

Excavation of the footings is expected to be achievable with a mechanical excavator in the sands and gravels and the weathered bedrock, although an allowance should be made for a breaker to aid excavation where the bedrock may be found to be less weathered.



The bedrock surface is plausibly expected to be irregular and the need for stepped foundations should be anticipated. Where this is the case, the height of the step should not exceed the thickness of the foundation, unless it forms part of a foundation designed by an Engineer in accordance with NHBC Technical Requirement R5. Foundation bottoms should be horizontal and steps, as near as possible, vertical.

Note: footings are expected to be on bedrock or deposits showing granular characteristics. However, the site profile is irregular and more cohesive strata has been observed on site. Foundation excavations should be taken through soft and impersistent cohesive layers to more uniform granular strata including weathered bedrock or bedrock. Where uniform firm to stiff or stiff cohesive deposits are uniformly encountered these will be suitable for traditional strip foundations. Based on the Low volume change potential of the cohesive deposits, A minimum foundation depth of 750mm is required for traditional strip footings outside the zone of influence of trees. Foundations within the zone of influence of trees/shrubs will need to be taken deeper to align with that the minimum depth and width criteria as per NHBC guidance chapter 4.2.7 Building near trees.

6.3.2 Transitional Plots

Where the plot is placed on the interface between the bedrock, sands and gravels (or cohesive strata), the formation should be observed on excavation to ensure uniform strata. The interface between the sands and gravels, and the weathered and competent bedrock is likely to be difficult to identify.

Where required the foundation excavation depth should be extended to provide strata uniformity. Alternatively foundations straddling compact granular/ bedrock boundaries may be provided with reinforcement to reduce differential settlement risks.

6.3.3 Trench Fill Foundations (taken as bearing strata depths of between 1.5 and 2.5m below FFL)

Where the suitable founding strata (medium dense sands and gravels, firm to stiff to stiff cohesive strata) are anticipated to be greater than 1.5m below the proposed ground levels, a Trench fill footing has been anticipated. This is estimated to equate to 21 plots as listed in Table X1 Rev 2 provided in Appendix E. Depending on the confirmation of ground conditions during construction, additional plots may require trench fill as opposed to shallow footings if the founding strata is found to be deeper than anticipated.

As with the shallow footings, the base of the trenches should be constructed with a horizontal base, and any steps required should be, as near as possible vertical.



6.3.4 Ground Improvement: Vibro stone columns/piled foundations

Plots where the suitable founding strata is anticipated to be greater than 2.5m below the proposed ground levels, are proposed for ground improvement or piled foundations. Founding strata is anticipated to be weathered bedrock or dense sands and gravels.

Foundations should be designed in accordance with NHBC guidance Chapters 4.4 and 4.5.

Based on the current investigation foundation depths are anticipated to be between 3 and 5m below proposed FFL. This is anticipated to be the foundation solution for 16 plots.

These plots include some where upfilling is required. It is required that all upfilling will be undertaken to a specification which allows the controlled placement of fill to an optimal compaction state. The advice of a competent ground improvement or piling specialist should be sought to clarify the most appropriate system.

6.4 Earthworks Considerations

6.4.1 Geotechnical Consideration

Where segregated and correctly handled there should be sufficient natural soils at or close to their optimum moisture content for compaction; therefore carefully selected cut materials should be re-useable in areas of fill.

Excavated materials should be stored in sealed stockpiles to prevent water ingress and degradation particularly of the cohesive material.

The reuse of material onsite, and the removal of excess material from the site should be covered by Material Management Plans which should be submitted to CL:AIRE prior to the final use of the material.

Existing stockpiles and generated stockpiles of Made Ground should undergo further testing validation testing prior to reuse to ensure they are suitable for re-use.

Ground Instability

Once exposed site materials may be subject to degradation and instability especially where wetted. Cut faces, for example for split level plots, may display mass instability and are likely to require temporary support or re-grading to a safe angle of repose.



6.4.2 Contamination

PJA has been informed by the client that there are no outstanding planning conditions relating to contamination at the site. Nevertheless, contaminants have been identified in samples which will require management during earthworks, to allow for the suitable re-use of materials and reduce offsite disposal.

During the initial investigation carried out under Atkins in 2016, visible Asbestos was recorded in Made Ground in WS301, located adjacent to a road in the western part of the site (see drawing No 1215/2183/1a in the IFA 2016 Factual report provided in Appendix C).

With reference to the proposed layout plan presented in Appendix B, this asbestos detect has been inferred to lie just outside the garden fence of plot 149 in the final development. Prior to any earthworks the extent of the Made Ground at this location of WS301 should be confirmed, excavated and segregated from other materials for further management. .

During the recent PJA investigation, elevated concentrations of Arsenic and Lead were identified in BH04 and TP01 respectively.

The elevated concentration in BH04 (39 mg/kg) is only slightly higher than the S4UL of 37mg/kg. This sample was taken from natural material and the arsenic concentration is broadly in-line with that from other samples from the natural soils. This marginal exceedance is therefore not considered to pose a significant risk to the end development.

The elevated concentration of Lead (780mg/kg) is significantly higher than the S4UL of 200mg/kg. The sample was taken from Made Ground in at TP01. With reference to the proposed cut and fill drawing presented in Appendix B, this location is outside the proposed earthworks. Future works in this area should consider careful excavation and segregation of materials. Groundworkers should wear appropriate PPE (dust masks & nitrile gloves) and remain vigilant for any visible evidence of contamination during the earthworks.

The contractor should remain vigilant for Made Ground and/ or visual signs of contamination during excavation and these materials should be stockpiled separately from other materials for additional testing prior to re-use.



Appendix A Coal Authority Report



Appendix B Third Party Drawings



Appendix C 2016 Factual Report



Appendix D Quantum Factual GI Report



Appendix E Table XI- Plot Foundations Table XI- Plot Foundations



Appendix F Chemical Data Screening