

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

Crymlyn Road, Skewen
Proposed Public Open Space Development
Earthworks Chemical Suitability Assessment

Report Reference: ESP.7203d.3348

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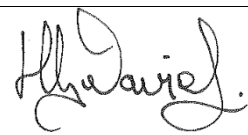
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Report Reference: **ESP.7203d.3348**

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Figure 1 – Investigation Point Plan

- Appendix A Phase 4 Validation Strategy (ESP, 2019)
- Appendix B Underground Utility Plans
- Appendix C Trial Pit Records
- Appendix D Geo-environmental Laboratory Test Results – Soils and Leachates
- Appendix E Laboratory Results Statistical Analysis – Soils and Leachates
- Appendix F Site Surveys

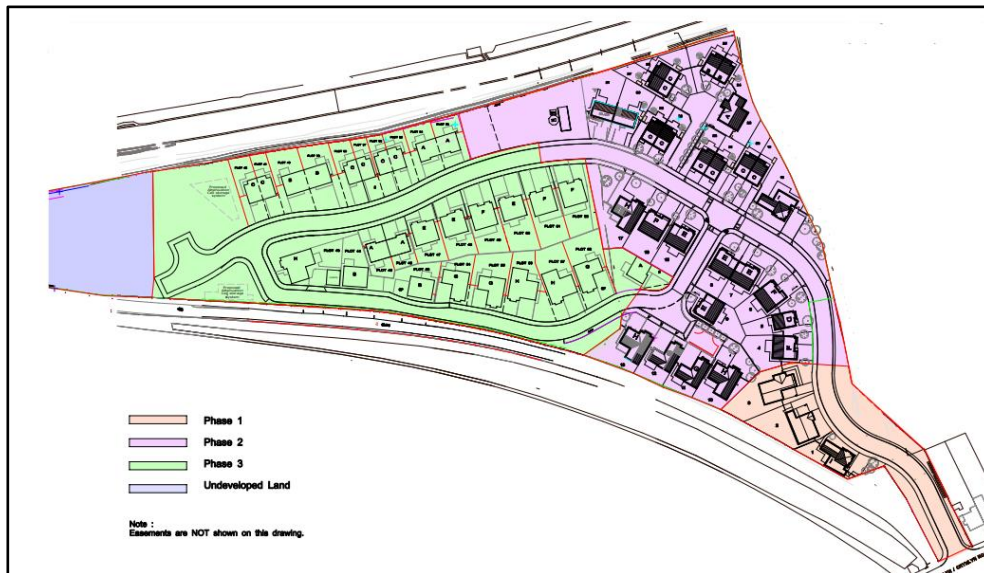
General Notes

General Construction Advice

1 Introduction

1.1 Background

Hale Construction (hereafter known as the Client) have constructed the first three phases of a residential development off Crymlyn Road, Skewen. Insert 1 below shows the proposed development to date. We understand the development was constructed in accordance with the planning permission received from Neath Port Talbot Council (Reference: *TBC by Client*).



Insert 1: Phase 1 to 3 Development Plan

Materials excavated from Phase 1 to 3 have been used to raise levels in Phase 4 (coloured blue in Insert 1). It is understood that this area is intended to be public open space however, in the long term, should planning approval be gained, there is a potential for residential development in this area.

The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake an intrusive investigation and assessment to demonstrate the chemical suitability of the materials used as part of the earthworks in the Phase 4 area considering the intended end use and to verify that they do not pose an environmental risk.

No assessment of the geotechnical suitability has been undertaken.

1.2 Objective and Scope of Works

We understand that regulatory approval for the Phase 4 earthworks is not currently obtained by the Client.

To achieve this, and to assess the chemical suitability of the materials used, a proposed validation strategy was designed by ESP in conjunction with the Client in August 2019 (Ref.7203d.3194.REV1, August 2019). The strategy was submitted to the Local Authority by the Client and subsequently approved on 14th June 2019 (Ref. Email- RE: Crymlyn Rd, Skewen – Phase 4 Validation Strategy). Further details on the strategy is presented in Section 2.7.3.

Upon completion, this report is to be submitted to the Local Authority (Neath Port Talbot County Borough Council – NPTCBC) by the Client for review. If the chemistry of the earthworks material is

considered acceptable, we understand regulatory approval for their placement in the Phase 4 area will be granted.

Previous investigations throughout Phases 1 to 4 were used to inform this assessment and information has been incorporated into this report where relevant. The previous investigation reports are presented in full in the appendices of the previous report provided by ESP (Ref.7203d.3194.REV1).

The contract for the undertaking of the validation works was awarded on the basis of a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 26th March 2015 (ref: hd/7203d.02.REV1). The investigation and assessment was undertaken between March and June 2020.

1.3 Report Format

This report includes a site overview and summary of previous investigations (Section 2), and details of the investigation undertaken of Eurocode EC7 and BS5930:2015 (Section 3), along with the updated Conceptual Ground Model (Section 4) and Generic Quantitative Risk Assessment (Section 5) of CLR11. An evaluation of the potential contamination risks and any remedial measures required to mitigate them is included in Section 6. However, it should be appreciated that this is a preliminary evaluation only, and will not generally meet the requirements of the Options Appraisal report of CLR11.

The report concludes with a summary of salient information and recommendations (Section 7).

This report is issued as a digital version only.

1.4 Limitations of Report

This report represents the findings of the brief relating to the proposed end use as detailed in Section 1.1 above. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site-specific requirements in accordance with good practice guidance.

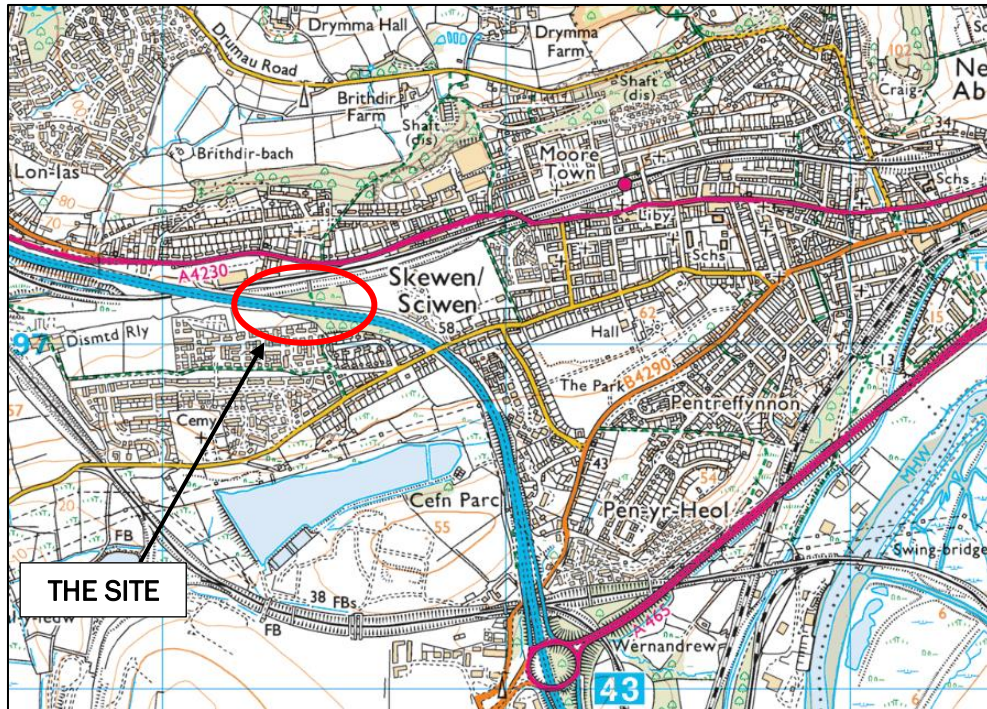
Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

2 Site Setting, Previous Investigation and Strategy Development

2.1 Site Location and Description

The site is located on the north side of Crymlyn Road and the M4 on the west side of the town of Skewen, Neath. The National Grid Reference of the centre of the site is (SS) 271651 197144 and the postcode is SA10 6ES. A site location plan is shown below as Insert 2.



Insert 2: Site Location Plan from Ordnance Survey 1:25,000 scale map.

The site description is largely based on a field reconnaissance and site inspection visit made at the site on the 3rd and 4th March 2020 during dry and sunny weather, and general views of the site are included as a series of photographs within the Plates section of this report.

The Phase 4 area currently consists of a sporadically grassed upper triangular plateau (see Plates 1 and 2) with a valley like feature on its north boundary which is wooded. Filling has occurred in part of the valley feature in the west portion and the fill is grassed (see Plate 3 and 4). A public footpath appears to extend through the site.

The ground surface comprised predominantly rough grass with occasional gravel and bare areas. The underlying material was visible in places and appeared to predominantly consist of re-worked glacial soils and apparent coal measures derived coarse grained materials (e.g. sandstone cobbles and boulders) with occasional to common man made materials e.g. bricks, concrete, tiles (see Plates 5 and 6).

2.2 On-site Utilities

As part of this assessment, service plans have been obtained by ESP from the utility companies – copies of this service information alongside plans provided by the Client are presented in Appendix B at the rear of this report.

Site observations and the utility plans indicate that the site is crossed by the following services:

- Mains water trunk pipes in the eastern and northern portions and a 90mm distribution pipe in the southern portion. On-site observations and information from the Client indicates the 90mm pipe terminates in the eastern portion of the site.
- BT, electricity and gas services are indicated adjacent to the site in the Phase 1 to 3 area, these are shown to terminate outside of the site boundary.
- Plans provided by the Client indicate underground attenuation tanks with associated drainage pipes in the north eastern and south eastern portion.

2.3 Previous Investigations and Assessments

ESP have previously completed an assessment comprising a review of information to date and the development of a validation strategy to demonstrate the suitability of the materials (Ref.7203d.3194.REV1, August 2019).

As part of the previous ESP assessment, earlier investigation information from these phases have been used to gain an initial understanding of the materials used as part of the earthworks. The following investigation information has been provided for Phases 1 to 3:

- Ateb Consult Soakaway Testing Records for Phase 2, dated 25th of January 2013 (Job No: 12/026);
- Ateb Consult Trial Pit Records and Laboratory Test Results for Phase 2, dated 15th of May 2013 (No Reference);
- Ateb Consult Factual Site Investigation and Contamination Testing Report for Phase 3, dated August 2015 (Ref: ref/22). *This report is presented within the Integral Geotechnique Report referenced below;* and
- Integral Geotechnique (Wales) Ltd Combined Desk Study and Site Investigation Report for Phases 3 and 4 dated October 2015 (Ref: 11677/MJE/15).
- Integral Geotechnique (Wales) Ltd Site Investigation Report for Phases 3 and 4 dated March 2016 (Ref: 11677/MJE/16/SI).

The above reports are presented as Appendices within the previous ESP report displayed in Appendix A. Where relevant, salient information is included in the following sections.

As part of this assessment, further survey information has also been reviewed which is detailed below and displayed in Appendix F:

- CB3 Consult Site Sections (based on LiDAR Survey) dated 20th April 2017 (Ref.C0859-C-SK01-01-Site Sections).

2.4 Site History

The previous investigation reports by Integral Geotechnique (Wales) Ltd (Report Refs: 11677/MJE/15 and 11677/MJE/16/SI) presented in Appendix A, indicates that prior to the recent residential development, no development had occurred in Phase 3 or 4, with it being used as

agricultural land. A railway cutting is present along the north boundary, however the former lines have now been removed. A cycle path followed by the M4 is located at the south boundary.

Review of the maps provided as part of the reports would also suggest limited development also occurred in the Phase 1 and 2 areas prior to the current development.

2.5 Geology

The information provided in the previous investigations and reference to the recent geological mapping (BGS, 2020), indicates the site is underlain by glacial soils overlying Upper Coal Measures bedrock.

Based on the site walkover undertaken in April 2019, at the surface, the earthworks material in the Phase 4 area appeared to predominantly consist of re-worked glacial soils and apparent coal measures derived coarse grained materials (e.g. sandstone cobbles and boulders) with occasional to common man made materials e.g. bricks, concrete, tiles (see Plates 5 and 6).

2.6 Hydrogeology and Hydrogeology

The underlying glacial soils are recorded as unproductive strata, whilst the Upper Coal Measures bedrock is classified as a Secondary A Aquifer.

The information provided in the previous investigation (Section 1.4) indicates a surface water course immediately to the north of the site. Reference to online mapping available on the National Resources Wales website (NRW, 2020), labels the feature as a drain and no connection to wider surface water network is indicated.

An oil refinery reservoir is the nearest significant surface water feature at some 300m to the south of the site.

The site works previously undertaken did not identified significant groundwater within the exploratory holes however, locally wet surface conditions were recorded.

2.7 Phase 4 Earthworks

2.7.1 Survey and Imagery Resources

The following summaries have been developed using survey information provided by the Client which is detailed below and presented in Appendix F, alongside historic aerial imagery available on Google Earth (2020):

- Ateb Consult, Existing Site Topographical Survey dated October 2015 (Ref.2001.pdf. Drawing No. 14/101)
- CB3 Consult, Site Sections (based on LiDAR Survey) dated 20th April 2017 (Ref.C0859-C-SK01-01-Site Sections).
- John Vincent Surveys Ltd., Crymlyn Road Phase 4 Site Survey dated January 2019 (Ref.Crymlyn19. Drawing No.14/19).
- CB3 Consult, Overlay Drawing dated 22nd May 2019 (Ref.C0981-Overlay.pdf).

2.7.2 Summary of Earthworks Undertaken

A review of online imagery (Google Earth), indicates that in December 2013, no obvious earthworks or development has occurred in the Phase 4 plot of land. The site is grassed with woodland. No surveys are available for the site at this time (i.e. prior to any earthworks). Construction has begun in the earlier phases.

On the aerial image dated 18th April 2015, earthworks have now occurred in the Phase 4 area and development had continued in the earlier phases. We understand the earthworks in Phase 4 at this time was part of the initial site preparation/clearance works. No filling has occurred in the former railway cutting. A topographic survey in 2015 is considered representative of the filling visually identified to have been undertaken.

Earthworks were then carried out during the period between the 2015 topographical survey and the 2017 LiDAR survey. This is evidenced in the imagery dated 27th June 2018, this is presumed to be the recent phase of earthworks. Further works then occurred between the 2017 LiDAR survey and the 2019 topographical survey and this included filling in the railway cutting.

As part of the previous assessment carried out by ESP, an estimation of the fill cover was calculated using two topographic surveys provided by the Client, one dated October 2015, which is prior to the main earthworks and one dated January 2019 which is post completion.

The topographic surveys indicate that fill depths ranged between 1m in the south increasing to 4m in the north with estimated filling of 4 to 5m within the area of the railway cutting in the north west.

2.7.3 Source and Methodology

It is understood that the earthworks material placed in the area of Phase 4 was sourced from the construction of Phase 1 to 3 of the development. The previous ESP report (Appendix A) provides a detailed summary of relevant information from earlier investigations during Phase 1 to 3 of the site.

No specification or methodology for the fill placement has been provided and it is understood that no Materials Management Plan was in place prior to the movement of the soils from the earlier phases to their final Phase 4 location. The Client indicated that as the soils were sourced from within the scheme boundary, were originally natural and considered uncontaminated (i.e. not beyond naturally elevated levels in the area), and it was their intention to use them in their natural state in the Phase 4 area, they understood they were exempt from the waste directive. We have been informed they did not intend to discard the material.

The Client is aware however they should have formally documented this intention within a soil resource plan, evidenced the re-use and prepared a validation report post completion to be submitted to the local authority.

2.7.4 Previous Laboratory Testing

Previous laboratory testing of the underlying soils undertaken in Phase 2 and 3 was used to provide an initial understanding of the contamination status of the fill materials and their suitability for the proposed end use in Phase 4. The findings of the laboratory testing is summarised below:

- Low levels of contamination was identified in the glacial/shallow bedrock soils with the exception of naturally elevated levels of lead which is not considered to be significant. One

sample contained non quantifiable levels of asbestos (chrysotile) which is considered anomalous.

- Testing of the topsoil indicated some exceedances (against residential guidelines), however these are considered to be a result of background contamination and it is understood no Topsoil was used as part of the earthworks fill.
- Testing of the Made Ground (comprising reworked natural soils) indicated generally low levels of contaminants with the exception of elevated levels of Arsenic. These are considered in accordance with the background levels recorded in the Topsoil. The levels are below the public open space guidelines, however they are above the residential.

2.7.5 Proposed Validation Strategy

As no formal re-use or management strategy was in place prior to the earthworks in Phase 4, it was proposed to implement a strategy to demonstrate to the local authority that the materials used in the Phase 4 area were suitable for use and they did not pose a risk to future end users or controlled waters receptors. The validation plan is detailed in the Phase 4 Validation Strategy (ESP, 2019) and is summarised below.

- ESP were to undertake a ground investigation comprising trial pitting to a depth sufficient to ensure progression beyond the base of the fill into the underlying natural material/Made Ground. In addition to the nature of the materials, this would confirm the fill depth across the site, and aid estimation of the volume placed.
- Investigation points placed on a 20 to 25m grid would provide sufficient disturbed samples to allow for vertical and horizontal classification of the material contamination status. This spacing would satisfy that of a detailed investigation in accordance with BS10175 (2017).
- Geo-environmental testing, comprising a standard suite of geo-environmental soil and leachate testing with additional contaminant testing where considered necessary, was proposed alongside on-site monitoring for volatile hydrocarbons.
- The testing strategy was designed in line with guidance provided by the Welsh Land Contamination Working Group (2013) for the chemical testing of imported materials.
- The laboratory test results would provide the basis for a Generic Quantitative Risk Assessment (GQRA) for both residential and public open space land use and 'Level One' Controlled Waters Risk Assessment.

The Validation Strategy outlined above was submitted to the Local Authorities Contaminated Land Officer (CLO) and subsequently approved on 14th June 2019 (Ref. Email- RE:Crymlyn Rd, Skewen – Phase 4 Validation Strategy).

3 Exploratory Investigation

3.1 Investigation Points

3.1.1 Introduction

The intrusive investigation comprising trial pitting was undertaken on the 3rd and 4th March 2020 in accordance with BS5930:2015 and BS10175:2017.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015, BS EN ISO 14688-1:2002, and BS EN ISO 14688-2:2018 along with published weathering schemes.

Descriptions and depths of the strata encountered are presented on the trial pit records in Appendix C. The investigation point positions are shown on Figure 1.

The ground levels indicated on the investigation point records are approximate only and have been interpolated from the topographical survey provided by the Client (Drawing No. 14/19, 2019). The coordinates shown on the investigation point records are approximate only and have been interpolated from recent online mapping.

3.1.2 Investigation Strategy

The local authority agreed investigation strategy is summarised in Section 2.7.3 and presented in full in Appendix A. The investigation points were generally constructed as per the intended strategy, spread across the site on an approximate 20m grid.

Constraints imposed by physical features on site including slopes, underground utilities and attenuation tanks did restrict investigation in some areas. However, where machine excavation was not possible, shallow hand excavated trial pits were undertaken to allow for full coverage of the site. As part of the investigation strategy, a large capacity (13 tonne) excavator was used to ensure the base of the fill material was identified however, in the area of the former cutting this was not achieved as the fill material extended beyond the reach of the excavator (TP01) as well as instability in the trial pits preventing further progression (TP02 and TP03).

Where hand excavated pits were undertaken, the base of the fill material was not encountered due to dense ground conditions.

During the investigation, two layers of fill were identified and have been described as Fill A and Fill B. Based on the available information, we consider both strata have been placed by the Client and for the purpose of the geo-environmental assessment, the strata have been considered as a whole. The earthworks fill was overlying natural Glacial Diamicton soils. The soils encountered are described further in Section 4.1.

Due to the presence of greater volumes of fill materials not previously anticipated, the sampling strategy was partially amended to include sampling of all strata encountered. The soils encountered and the adopted sampling strategy are detailed below in Sections 4.1 and 3.3 respectively.

The investigation point locations and constraints are indicated on Figure 1.

3.1.3 Machine Excavated Trial Pits

11no. trial pits (TP1 to TP11) were excavated across the site between 3rd and 4th March 2020 using a 13 tonne tracked hydraulic excavator. The trial pits were excavated to depths of between 2.0 and 4.4m. The trial pit records are presented as Appendix C, and their positions are shown on Figure 1.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records.

On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket, and the Topsoil reinstated on the surface. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

3.1.4 Hand Excavated Trial Pits

5no. shallow hand excavated trial pits (HPA - HPE) were excavated in the eastern portion of the site where underground utilities were present, using hand excavation tools. The trial pits were excavated to a maximum depth of 0.4m. The trial pit records are presented as Appendix C, and their positions are shown on Figure 1.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records.

On completion, the pits were backfilled with arisings in layers and compacted by hand.

3.2 Monitoring for Volatile Hydrocarbons

A photo-ionisation detector (PID) was used during the trial pitting to measure the levels of total volatile hydrocarbons present in the recovered soils.

Analysis was carried out only on selected samples to provide an overall assessment of the soils encountered, both vertically within the strata encountered and spatially across the site.

Headspace analyses were undertaken whereby samples of the soil were collected in sealed plastic bags from the exploratory holes and then left for a period of time (in the sun to allow any volatiles present to escape into the headspace above the soil). The PID was then used to measure the levels of total volatile organic compounds (VOC) within the headspace above the sampled soils.

The results of the headspace testing are presented in the trial pit records in Appendix C.

3.2.1 Site Evidence of Contamination

No direct visual/olfactory evidence of contamination was identified in the exploratory holes.

Within the more recent Fill A, occasional man-made materials including but not limited to brick, concrete, timber and metal was encountered.

Man-made materials were also identified within Fill B generally across the site. The amount and variety of man-made constituents was generally greater within Fill B compared to Fill A. The materials encountered in this strata include, but it not limited to, brick, concrete, timber, metal tile, tarpaulin, plastic. Fill B also contained organic materials e.g. partially decomposed roots, branches and grass (see Plate 10).

The materials generally appeared to be building materials from the residential development that had been incorporated into the natural soils.

3.3 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil and leachate generated from shallow soils.

The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment (see Section 4.3).

3.3.1 Soil Samples

The Validation Strategy (ESP, 2019) as agreed by the Client and Local Authority allowed for a total of 20no. earthworks material samples and 5no. samples of natural material to be analysed.

Following the site works, additional testing was proposed and agreed with the Client, in total 29no. samples of earthworks material (both Fill A and Fill B) and 5no. samples of the underlying natural soils were analysed for contaminants typically present on brownfield sites in the UK. Samples were selected for testing across a range of depths within the strata across the site.

The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polycyclic aromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value.

Once the above analysis was complete, the results indicated elevated levels of PAH's in localised samples of the earthworks material (TP05 and TP14). These samples were subsequently analysed for the following to assess the range of hydrocarbon contamination potentially present:

- Petroleum hydrocarbons (CWG ali/aro carbon banded C₅ to C₃₅)

The geo-environmental soil test results are presented in Appendix D.

3.3.2 Leachate Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from 13no. samples of earthworks material (Fill A and B) and 5no. samples of natural soils recovered from the exploratory holes. The leachate preparation was carried out in accordance with BS EN 12457, at a 10:1 eluate ratio.

The resulting leachate was analysed for the following determinants:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- Aluminium, antimony, cobalt, molybdenum manganese, silver, sodium, tin;
- US EPA 16 polycyclic aromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Cyanide, soluble sulphate, pH value;

Elevated levels of PAH's identified in 2no. samples of the earthworks material (TP05 and TP14). These samples were subsequently analysed for the following to assess the range of hydrocarbon contamination potentially present:

- Petroleum hydrocarbons (CWG ali/aro carbon banded C₅ to C₃₅);

The results of the leachate tests are presented in Appendix D.

4 Development of the Conceptual Model

4.1 Conceptual Ground Model - Geology

The exploratory holes have identified the site to be generally underlain by a covering of earthworks material encountered as two distinct layers described as Fill A and Fill B. As discussed in Sections 2.7.4 and 3.1.2, we consider both fill materials were placed by the Client as part of earthworks relating to the development.

The earthworks material was overlying natural Glacial Diamicton soils. These strata are discussed in more detail in the following sections.

Topsoil: encountered at the surface sporadically across the site and generally comprising a dark brown sandy gravelly clay with rootlets. Where significant topsoil was absent, grass directly over Fill A was recorded.

Earthworks Fill A: in the area of the railway cutting the fill was deepest with a maximum depth of 4.4m. Across the remainder of the site on the level plateau, Fill A was encountered to depths of between 0.4m and 2.0m in all trial pits with the exception of TP06.

In the area of the former railway cutting, Fill A generally comprised firm to stiff dark brownish grey slightly silty sandy gravelly clay with medium cobble content. Cobbles and gravels were subangular to subrounded weathered sandstone. Occasional inert man-made constituents were encountered throughout including, brick, timber, metal, rubber, wire, concrete, tarmac and tile.

Across the remainder of the site Fill A generally comprised firm greyish brown slightly silty slightly gravelly clay and medium dense slightly clayey gravelly sand with low to medium cobble content as above. Occasional man-made constituents were encountered throughout including, brick, timber, metal, rubber, fabric, concrete, glass and tile. The proportion of man-made materials was generally consistent across the site however, some localised areas contained more man-made components (e.g. TP08 and TP14).

Fill A was encountered in all shallow trial pits (HP-A to HP-E) as above with rare to occasional man-made materials encountered, including brick and concrete fragments.

No evidence of disturbed topsoil was recorded within Fill A.

Based on the exploratory holes undertaken consider the approximate volume of Fill A to be in the order of 4,000 to 5,000m³.

Earthworks Fill B: encountered in the main plateau area of the site to maximum depths of between 1.1 to 3.0m generally as a firm to stiff dark greyish black and brown slightly sandy silty gravelly clay with low cobble content. Organic matter comprising partially decomposed grass, roots and branches was encountered in varying portions within Fill B. Occasional to common man-made constituents were encountered including but not limited to, fabric, brick, plastic, rope, brick, concrete and metal. Generally, Fill B contained a higher proportion and greater variety of man-made materials compared with Fill A.

Fill B was not encountered in TP02 to TP04 as the depth of Fill A extended further than the reach capacity of the excavator or the trial pit collapsed due to instability. The material was also not encountered in the hand excavated trial pits (HP-A to HP-E) due to the shallow nature of the excavations. The presence of Fill B below Fill A in these areas cannot be discounted.

Based on the exploratory holes undertaken consider the approximate volume of Fill B to be in the order of 4,000 to 5,000m³. Therefore, we consider the approximate volume of Made Ground to be in the order of 8,000 to 10,000m³.

Glacial Diamicton: encountered beneath the earthworks material (Fill A and Fill B) in the main plateau area of the site and generally comprising a firm orangish brown slightly gravelly silty clay with low to medium cobble content. Gravels and cobbles comprised subangular to subrounded weathered sandstone.

Coarse grained Glacial Diamicton generally comprising medium dense orangish brown silty gravelly sand with low to medium cobble content was encountered in trial pits TP04 to TP06 and TP09.

Glacial Diamicton was not encountered in TP01 to TP03 in the area of the railway cutting or the shallow trial pits (HP-A to HP-E) due to the limitations of the excavation methods and trial pit instability.

Coal Measures bedrock: not encountered during the investigation however, it is anticipated to underlie the Glacial Diamicton at a shallow depth. The previous investigation (relating to Phase 3 and 4) identified possible weathered bedrock between 1.1 and 2.6m depth (Appendix A). The bedrock also outcrops in the side of the historic railway cutting.

4.2 Conceptual Ground Model - Hydrogeology

4.2.1 Groundwater Bodies

The groundwater conditions identified in the investigation are summarised in Table 1 below:

Table 1: Summary of Groundwater Ingress in the Investigation

Hole ID	Stratum	Comment on groundwater encountered
HP-A to HP-D	Fill A	Minor groundwater seepage recorded from ground level.
TP01	Fill A	Groundwater not encountered.
TP02	Fill A	Groundwater not encountered.
TP03	Fill A	Groundwater not encountered.
TP04	-	Groundwater not encountered.
TP05	-	Groundwater not encountered.
TP06	Glacial Diamicton	Slow groundwater ingress recorded at 1.8m depth.
TP07	Fill B	Fast groundwater ingress recorded at 3.0m rising to 2.4m depth over 5mins.
TP08	Fill A	Minor groundwater seepage recorded above 1.0m depth.
TP09	-	Groundwater not encountered.
TP10	Fill B	Minor groundwater seepage recorded at 0.8m depth.
TP11	Fill A	Minor groundwater seepage recorded above 0.7m depth.
TP12	Fill A	Minor groundwater seepage recorded above 0.7m depth.
TP13	Fill A	Minor groundwater seepage recorded above 0.6m depth.
TP14	Fill A/Fill B	Minor groundwater seepage recorded above 1.0m depth.
Notes:		
1. Full details of groundwater ingress presented on exploratory hole records in Appendix C.		

Based on the information available to date, we consider that the main groundwater body beneath the site is within underlying Upper Coal Measures. However, a discontinuous perched water table was present at shallow depth (approx. 1 to 3m depth) within the earthworks materials. Minor groundwater seepages were also recorded within the Glacial Diamicton.

4.3 Chronic Risks to Human Health – Generic Assessment of Risks

4.3.1 Assessment Methodology

The long-term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

4.3.2 Assessment Criteria

In 2013, CL:AIRE published the Category 4 Screening Levels (C4SL – CL:AIRE, 2013) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. The C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). The C4SL have also only been published for a limited number of contaminants commonly identified in contaminated land risk assessments at present (arsenic, cadmium, chromium VI, lead, benzene, benzo[a]pyrene). However, the C4SL have been published for a range of land uses, including residential, commercial, allotments and two types of public open space.

The C4SL are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e. as part of standard development investigations). The Welsh Local Government Association and Natural Resources Wales (WLGA/NRW) have confirmed that, *'where the site conditions are applicable to the land use scenarios adopted in their calculation, the C4SL levels can be used as screening tools'* for development site risk assessments (WLGA/NRW, 2017). The C4SL have also been accepted by the NHBC for use as generic screening levels on residential developments in England and Wales (NHBC, 2014). Given this, where available and applicable, the C4SL have been adopted as the Generic Assessment Criteria in this assessment.

Where no C4SL is currently available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) (Nathanail et al, 2015) have been adopted. These assessment criteria adopt updated toxicological data and exposure models, and the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

Where no C4SL or S4UL is available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) – note several SGV have been withdrawn since originally published. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments – and not public open space).

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space).

Details of the Generic Assessment Criteria (GAC) adopted for each contaminant are presented on the assessment tables in the following section.

As discussed in Section 1.1., it is understood that the Phase 4 area is intended to be public open space however, in the long term, should planning approval be gained, there is a potential for residential development in this area. As such, the results have been compared against the GAC for public open space around residential properties as well as those for residential land use with plant uptake.

The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 0.6 to 3.1%. Therefore, for the purposes of this assessment, GAC for a soil organic content of 1% has been adopted. This again is considered a conservative approach for the majority of the soils at the site.

4.3.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants are outlined below:

- 29no. Earthworks Material – Fill A/Fill B.
- 5no. Natural Soil – Glacial Diamicton.

Reference to guidance on frequency of testing prepared by the Welsh Land Contamination Working Group (2013) indicates that where volumes of material exceed 1000m³, pre-set sampling requirements by volume may not be financially feasible, as such it is recommended an appropriate sampling scheme is agreed with the CLO. Given that the amount of material exceeds 1000m³, this approach has been adopted, see section 2.7.3. Based on the approximate volume of fill (8,000 to 10,000 m³), the testing equates to 1no. test per 275 to 350m³ of fill material which we consider is robust.

The results have been analysed relative to the above soils types. If any exceedances are identified, a statistical analysis based on particular averaging areas has been undertaken to further assess the risks (Section 4.5.3). The risks from asbestos are considered further in Section 4.3.4.

The results of the Generic Quantitative Risk Assessment for the proposed development are presented in Tables 2 and 3 below. The results have been compared to guideline values for both public open space (residential) (Table 2) and residential with plant uptake (Table 3). It should be appreciated that if the development were to change, the following assessment should be reviewed and, if necessary, updated.

Table 2: Generic Assessment of Human Health Risks (Public open space near residential properties)

Determinand	Range Recorded Earthworks Materials - Fill A and Fill B (29no. Samples)	Range Recorded Glacial Diamicton (5no. Samples)	GAC	Source of GAC	Exceedances
Metals and Semi-metals					
Arsenic	13 – 24 mg/kg	16 – 19 mg/kg	170mg/kg	C4SL ²	None
Barium ⁶	56 – 85 mg/kg	64 – 84 mg/kg	1,300mg/kg	CL:AIRE/EIC ⁵	None
Beryllium	0.4 – 0.8 mg/kg	0.5 – 0.6 mg/kg	63mg/kg	S4UL ⁴	None
Boron	0.4 – 0.5 mg/kg	0.4 – 0.5 mg/kg	290mg/kg	S4UL ⁴	None
Cadmium	0.5 – 0.9 mg/kg	0.6 – 0.7 mg/kg	555mg/kg	C4SL ²	None
Chromium (total) ⁷	13 – 18 mg/kg	13 – 16 mg/kg	33,000mg/kg	S4UL ⁴	None
Chromium (hexavalent)	<1.0 mg/kg	<1.0 mg/kg	220mg/kg	C4SL ²	None
Copper	31 – 100 mg/kg	35 – 42 mg/kg	44,000mg/kg	S4UL ⁴	None
Lead	24 – 240 mg/kg	29 – 35 mg/kg	1,300mg/kg	C4SL ²	None
Mercury ⁸	<0.05 – 0.07 mg/kg	0.06 – 0.07 mg/kg	240mg/kg	S4UL ⁴	None
Nickel	17 – 27mg/kg	18 – 20 mg/kg	800mg/kg	S4UL ⁴	None
Selenium	<0.5 – 1.1 mg/kg	<0.5 – 0.6 mg/kg	1,800mg/kg	S4UL ⁴	None
Vanadium	16 – 25 mg/kg	17 – 22 mg/kg	410mg/kg	S4UL ⁴	None
Zinc	88 – 130 mg/kg	85 – 100 mg/kg	170,000mg/kg	S4UL ⁴	None
Polyaromatic Hydrocarbons (PAH)					
Acenaphthene	<0.03 – 2.4 mg/kg	<0.03 mg/kg	29,000mg/kg	S4UL ^{4,9}	None
Acenaphthylene	<0.03 mg/kg	<0.03 mg/kg	29,000mg/kg	S4UL ^{4,9}	None
Anthracene	<0.03 – 2.0 mg/kg	<0.03 mg/kg	150,000mg/kg	S4UL ^{4,9}	None
Benzo(a)anthracene	<0.03 – 1.3 mg/kg	<0.03 mg/kg	49mg/kg	S4UL ^{4,9}	None
Benzo(a)pyrene	<0.03 – 0.94 mg/kg	<0.03 mg/kg	11mg/kg	C4SL ^{2,9}	None
Benzo(b)fluoranthene	<0.03 – 1.2 mg/kg	<0.03 mg/kg	13mg/kg	S4UL ^{4,9}	None
Benzo(ghi)perylene	<0.03 – 0.53 mg/kg	<0.03 mg/kg	1,400mg/kg	S4UL ^{4,9}	None
Benzo(k)fluoranthene	<0.03 – 0.56 mg/kg	<0.03 mg/kg	370mg/kg	S4UL ^{4,9}	None
Chrysene	<0.03 – 1.2 mg/kg	<0.03 mg/kg	93mg/kg	S4UL ^{4,9}	None
Dibenzo(a,h)anthracene	<0.03 – 0.11 mg/kg	<0.03 mg/kg	1.1mg/kg	S4UL ^{4,9}	None
Fluoranthene	<0.03 – 4.7 mg/kg	<0.03 mg/kg	6,300mg/kg	S4UL ^{4,9}	None
Fluorene	<0.03 – 1.7 mg/kg	<0.03 mg/kg	20,000mg/kg	S4UL ^{4,9}	None
Indeno(123-cd)pyrene	<0.03 – 0.5 mg/kg	<0.03 mg/kg	150mg/kg	S4UL ^{4,9}	None
Naphthalene	<0.03 – 3.5 mg/kg	<0.03 mg/kg	1,200mg/kg*	S4UL ^{4,9}	None
Phenanthrene	<0.03 – 6.1 mg/kg	<0.03 mg/kg	6,200mg/kg	S4UL ^{4,9}	None
Pyrene	<0.03 – 3.6 mg/kg	<0.03 mg/kg	15,000mg/kg	S4UL ^{4,9}	None

Table 2 cont.: Generic Assessment of Human Health Risks (Public open space near residential properties)

Determinand	Range Recorded Earthworks Materials - Fill A and Fill B (29no. Samples)	Range Recorded Glacial Diamicton (5no. Samples)	GAC	Source of GAC	Exceedances
Aliphatic Petroleum Hydrocarbons (Equivalent Carbon Number)					
Ali EC 5-6	<0.01 mg/kg	No Testing Undertaken	42mg/kg	S4UL ^{4,9}	None
Ali EC 6-8	<0.01 mg/kg		100mg/kg		None
Ali EC 8-10	<0.01 mg/kg		27mg/kg		None
Ali EC 10-12	<1.5 mg/kg		130mg/kg*		None
Ali EC 12-16	<1.2 mg/kg		1,100mg/kg*		None
Ali EC 16-35	<4.9 mg/kg		65,000mg/kg*		None
Aromatic Petroleum Hydrocarbons (Equivalent Carbon Number)					
Aro EC 5-7	<0.01 mg/kg	No Testing Undertaken	70mg/kg	S4UL ^{4,9}	None
Aro EC 7-8	<0.01 mg/kg		130mg/kg		None
Aro EC 8-10	<0.01 mg/kg		34mg/kg		None
Aro EC 10-12	<0.9 mg/kg		74mg/kg		None
Aro EC 12-16	<0.5 mg/kg		140mg/kg		None
Aro EC 16-21	<0.6 mg/kg		260mg/kg		None
Aro EC 21-35	<1.4 mg/kg		1,100mg/kg		None
Other Organic Compounds					
Phenol	<0.3 – 0.3 mg/kg	<0.3 mg/kg	280mg/kg	S4UL ^{4,9}	None
Notes: 1. Assessment for public open space near residential properties. 2. C4SL: Category 4 Screening Level, published by CL:AIRE. 3. SGV: Soil Guideline Value published by Environment Agency. 4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved. 5. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission. 6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers. 7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted. 8. GAC for inorganic mercury adopted. 9. GAC for organic compounds based on 1% soil organic content. 10. Exceedances highlighted in red and bold. 11. Laboratory results presented in Appendix D. * GAC exceeds solubility or vapour saturation limit.					

Table 3: Generic Assessment of Human Health Risks (Residential With Plant Uptake)

Determinand	Range Recorded Earthworks Materials - Fill A/Fill B (29no. Samples)	Range Recorded Glacial Diamicton (5no. Samples)	GAC	Source of GAC	Exceedances
Metals and Semi-metals					
Arsenic	13 – 24 mg/kg	16 – 19 mg/kg	37mg/kg	C4SL ²	None
Barium ⁶	56 – 85 mg/kg	64 – 84 mg/kg	1,300mg/kg	CL:AIRE/EIC ⁵	None
Beryllium	0.4 – 0.8 mg/kg	0.5 – 0.6 mg/kg	1.7mg/kg	S4UL ⁴	None
Boron	0.4 – 0.6 mg/kg	0.4 – 0.5 mg/kg	290mg/kg	S4UL ⁴	None
Cadmium	0.5 – 0.9 mg/kg	0.6 – 0.7 mg/kg	26mg/kg	C4SL ²	None
Chromium (total) ⁷	13 – 18 mg/kg	13 – 16 mg/kg	910mg/kg	S4UL ⁴	None
Chromium (hexavalent)	<1.0 mg/kg	<1.0 mg/kg	21mg/kg	C4SL ²	None
Copper	31 – 100 mg/kg	35 – 42 mg/kg	2,400mg/kg	S4UL ⁴	None
Lead	24 – 240 mg/kg (1 of 29)	29 – 35 mg/kg	200mg/kg	C4SL ²	1no. Earthworks Material
Mercury ⁸	<0.05 – 0.07 mg/kg	0.06 – 0.07 mg/kg	40mg/kg	S4UL ⁴	None
Nickel	17 – 27mg/kg	18 – 20 mg/kg	130mg/kg	S4UL ⁴	None
Selenium	<0.5 – 1.1 mg/kg	<0.5 – 0.6 mg/kg	250mg/kg	S4UL ⁴	None
Vanadium	16 – 25 mg/kg	17 – 22 mg/kg	410mg/kg	S4UL ⁴	None
Zinc	88 – 130 mg/kg	85 – 100 mg/kg	3,700mg/kg	S4UL ⁴	None
Polyaromatic Hydrocarbons (PAH)					
Acenaphthene	<0.03 – 2.4 mg/kg	<0.03 mg/kg	210mg/kg	S4UL ^{4,9}	None
Acenaphthylene	<0.03 mg/kg	<0.03 mg/kg	170mg/kg	S4UL ^{4,9}	None
Anthracene	<0.03 – 2 mg/kg	<0.03 mg/kg	2,400mg/kg	S4UL ^{4,9}	None
Benzo(a)anthracene	<0.03 – 1.3 mg/kg	<0.03 mg/kg	7.2mg/kg	S4UL ^{4,9}	None
Benzo(a)pyrene	<0.03 – 0.94 mg/kg	<0.03 mg/kg	5mg/kg	C4SL ^{2,9}	None
Benzo(b)fluoranthene	<0.03 – 1.2 mg/kg	<0.03 mg/kg	2.6mg/kg	S4UL ^{4,9}	None
Benzo(ghi)perylene	<0.03 – 0.53 mg/kg	<0.03 mg/kg	320mg/kg	S4UL ^{4,9}	None
Benzo(k)fluoranthene	<0.03 – 0.56 mg/kg	<0.03 mg/kg	77mg/kg	S4UL ^{4,9}	None
Chrysene	<0.03 – 1.2 mg/kg	<0.03 mg/kg	15mg/kg	S4UL ^{4,9}	None
Dibenzo(a,h)anthracene	<0.03 – 0.11 mg/kg	<0.03 mg/kg	0.24mg/kg	S4UL ^{4,9}	None
Fluoranthene	<0.03 – 4.7 mg/kg	<0.03 mg/kg	280mg/kg	S4UL ^{4,9}	None
Fluorene	<0.03 – 1.7 mg/kg	<0.03 mg/kg	170mg/kg	S4UL ^{4,9}	None
Indeno(123-cd)pyrene	<0.03 – 0.5 mg/kg	<0.03 mg/kg	27mg/kg	S4UL ^{4,9}	None
Naphthalene	<0.03 – 3.5 mg/kg (1 of 29)	<0.03 mg/kg	2.3mg/kg	S4UL ^{4,9}	1no. Earthworks Material
Phenanthrene	<0.03 – 6.1 mg/kg	<0.03 mg/kg	95mg/kg	S4UL ^{4,9}	None
Pyrene	<0.03 – 3.6 mg/kg	<0.03 mg/kg	620mg/kg	S4UL ^{4,9}	None

Table 3 cont.: Generic Assessment of Human Health Risks (Residential With Plant Uptake)

Determinand	Range Recorded Earthworks Materials - Fill A/Fill B (29no. Samples)	Range Recorded Glacial Diamicton (5no. Samples)	GAC	Source of GAC	Exceedances
Aliphatic Petroleum Hydrocarbons (Equivalent Carbon Number)					
Ali EC 5-6	<0.01 mg/kg	No Testing Undertaken	42mg/kg	S4UL ^{4,9}	None of 2
Ali EC 6-8	<0.01 mg/kg		100mg/kg		None of 2
Ali EC 8-10	<0.01 mg/kg		27mg/kg		None of 2
Ali EC 10-12	<1.5 mg/kg		130mg/kg*		None of 2
Ali EC 12-16	<1.2 mg/kg		1,100mg/kg*		None of 2
Ali EC 16-35	<4.9 mg/kg		65,000mg/kg*		None of 2
Aromatic Petroleum Hydrocarbons (Equivalent Carbon Number)					
Aro EC 5-7	< 0.01 mg/kg	No Testing Undertaken	70mg/kg	S4UL ^{4,9}	None of 2
Aro EC 7-8	< 0.01 mg/kg		130mg/kg		None of 2
Aro EC 8-10	< 0.01 mg/kg		34mg/kg		None of 2
Aro EC 10-12	< 0.9 mg/kg		74mg/kg		None of 2
Aro EC 12-16	< 0.5 mg/kg		140mg/kg		None of 2
Aro EC 16-21	< 0.6 mg/kg		260mg/kg		None of 2
Aro EC 21-35	< 1.4 mg/kg		1,100mg/kg		None of 2
Other Organic Compounds					
Phenol	<0.3 – 0.3 mg/kg	<0.3 mg/kg	280mg/kg	S4UL ^{4,9}	None
Notes:					
1. Assessment for residential land use <u>with home-grown produce uptake</u> (apart from barium – see Note 6 below).					
2. C4SL: Category 4 Screening Level, published by CL:AIRE.					
3. SGV: Soil Guideline Value published by Environment Agency.					
4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.					
5. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.					
6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers.					
7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.					
8. GAC for inorganic mercury adopted.					
9. GAC for organic compounds based on 1% soil organic content.					
10. Exceedances highlighted in red and bold.					
11. Laboratory results presented in Appendix D.					
* GAC exceeds solubility or vapour saturation limit.					

Overall the levels of determinands tested were generally consistent across the earthworks material and natural soils. In general, the maximum levels of PAH's were higher within the earthworks material however, many were below levels of detection as per the natural soils and the majority of the results fell below the most stringent residential guideline values.

Table 2 indicates that all determinands fell below their respective guideline values for public open space (residential).

From Table 3, the majority of determinands analysed fell below the adopted residential with plant uptake guideline values. However, elevated levels of Lead and Naphthalene were recorded in one sample, TP14 at 0.70m depth (Fill A). Where elevated PAH values were recorded within TP05 and TP14, further petroleum hydrocarbon testing (TPH CWG) was undertaken and the results indicate that the TPH levels were below the limit of detection.

A further statistical analysis of the data considering individual averaging areas is considered warranted and follows in Section 4.4.5.

4.3.4 Asbestos

No evidence of asbestos was identified in the samples analysed.

4.3.5 Statistical Assessment of Soil Results

Elevated levels of lead and naphthalene were identified in one sample of the earthworks material (Fill A) when compared to the residential with plant uptake Generic Assessment Criteria (GAC). The levels of lead and naphthalene have therefore been assessed statistically in accordance with CIEH/CL:AIRE (2008). The analyses are presented as Appendix E and discussed below.

4.3.5.1 Lead

The levels of Lead varied between 24 and 240mg/kg, with a sample mean of 38.4 mg/kg and a standard deviation of 39.3 mg/kg for a sample size of 29. The true mean (US95) is 70.2mg/kg.

An assessment of the data has identified the value from TP14 at 0.7m depth to be an outlier (defined as a result that lies more than two standard deviations from the mean). However, even without removing the outlier, the analysis of the robust data set indicates that the true mean of the lead levels (upper confidence limit) within the earthworks material across the site is less than the residential GAC (the critical concentration), with a statistical evidence level of 100%.

4.3.5.2 Naphthalene

The levels of Naphthalene varied between <0.03 and 3.5mg/kg, with a sample mean of 0.15 mg/kg and a standard deviation of 0.64 mg/kg for a sample size of 29. The true mean (US95) is 0.67mg/kg.

An assessment of the data has identified the value from TP14 at 0.7m depth to be an outlier (defined as a result that lies more than two standard deviations from the mean). However, even without removing the outlier, the analysis of the robust data set indicates that the true mean of the Naphthalene levels within the fill across the site is less than the residential GAC (the critical concentration), with a statistical evidence level of 100%.

4.4 Risk to Controlled Waters - Level One Assessment

4.4.1 Methodology

The potential impact of contamination originating at the site on controlled waters in the area of the site (i.e. groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006).

Levels of leachable contamination within the soil samples recovered at the site have been analysed, which represents a 'Level One' risk assessment (Carey et al, 2006).

4.4.2 Assessment Criteria

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

Based on the information available (Sections 2.3 and 2.6), the following points are considered salient with regards to the risk of controlled water receptors at the site:

- The Upper Coal Measures bedrock is classified as a Secondary A aquifer, where the groundwater could be abstracted for potable use in the future.
- The underlying glacial soils are classified as Unproductive Strata and generally contain a high fraction of fines.
- There are no surface water receptors in the vicinity of the site (the nearest being an oil refinery reservoir 300m to the south).
- A drain is noted on the northern boundary of the site, however is not indicated to be in connection with a wider surface water network or is considered to be sensitive (Section 2.6).

Given the available information, we consider that the most vulnerable receptor with regards to leachable and mobile contamination would be the groundwater beneath the site and our assessment has concentrated on this receptor.

Groundwater as a General Resource:

In order to assess the potential risk to groundwater as a general resource beneath the site, we have adopted the '*concentrations of hazardous substances within groundwater below which the danger of deterioration of the groundwater quality is avoided*' published by UKTAG (2016) have been adopted as assessment criteria. These UKTAG concentrations have been calculated from thresholds designed to be protective of drinking water, so may be conservative in this instance. Therefore, an exceedance may not necessarily indicate an unacceptable risk.

Hazardous Substances:

Some contaminants which can impact on controlled waters have been classed as hazardous substances (JAGDAG, 2019) and include arsenic, lead, mercury, and some of the polyaromatic and petroleum hydrocarbon compounds. Natural Resources Wales (NRW) require that the entry of hazardous substances into controlled waters is phased out, or at least any further entry should be minimised. The remaining contaminants are classed as non-hazardous. The classification of each determinand analysed is presented in Table 4.

Petroleum Hydrocarbons:

There are currently no EU or UK guidelines for ethylbenzene and the World Health Organisation criteria (WHO, 2011) have been adopted for this compound. Similarly, with the exception of the BTEX compounds, there are no published assessment criteria for petroleum hydrocarbons within controlled waters. The Environment Agency/NRW have previously stipulated an assessment criteria of 10µg/l for all bands of petroleum hydrocarbons, and this has been used tentatively as the assessment criteria. However, it should be appreciated that this only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk.

The actual assessment criteria adopted are shown in the following table(s), and further details on them can be found in the respective published documents.

4.4.3 Assessment of Leachate Test Results

The samples selected for leachate testing are outlined below:

- 13no. Made Ground – Fill A/Fill B
- 5no. Natural Soil – Glacial Diamicton

The results of the leachate testing for each strata and their comparison to the relevant assessment criteria are presented in Table 4 below, based on the underlying groundwater as the most vulnerable receptor.

Table 4: Level One Controlled Waters Risk Assessment – Leachate Results (General Groundwater)

Compound	Range Recorded Earthworks Material - Fill A/Fill B (13no. Samples)	Range Recorded Glacial Diamicton (5no. Samples)	UKTAG ⁵	Exceedances
Metals				
Arsenic ¹	0.47 – 2.5 µg/l	0.1 – 1.5 µg/l	5.0µg/l	None
Chromium VI ^{1,3}	<0.25 – 0.44 µg/l	<0.25 – 1.4 µg/l	5.0µg/l	None
Lead ¹	0.15 – 0.66 µg/l	<0.09 – 1.0 µg/l	5.0µg/l	None
Mercury ¹	<0.01 µg/l	<0.01 µg/l	0.5µg/l	None
Polyaromatic Hydrocarbons				
Anthracene ¹	<0.01 – 0.03 µg/l	<0.01 – 0.01 µg/l	0.05µg/l	None
Benzo[a]pyrene¹	<0.01 – 0.05 µg/l (12 of 13)⁷	<0.01 µg/l	0.005µg/l	12no. Earthworks Material⁷
BbF¹	<0.01 – 0.12 µg/l (5 of 13)	<0.01 – 0.02 µg/l	0.05µg/l	5no. Earthworks Material
BghiP¹	<0.01 – 0.08 µg/l (1 of 13)	0.01 – 0.03 µg/l	0.05µg/l	1no. Earthworks Material
BkF¹	<0.01 – 0.12 µg/l (1 of 13)	<0.01 – 0.01 µg/l	0.05µg/l	1no. Earthworks Material
IDP¹	<0.01 – 0.06 µg/l (1 of 13)	<0.01 µg/l	0.05µg/l	1no. Earthworks Material
Notes: - Hazardous substance (JAGDAG, 2019). - Non-hazardous substance (JAGDAG, 2019). - All chromium present assumed to be chromium VI (conservative approach). - Assessment based on non-potable groundwater beneath the site. - UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only. - Exceedances indicated in bold and red as shown. - Where results are below the limit of detection but above the UKTAG, these have not been considered exceedances. Test results presented in Appendix C. Key to PAH compounds: BbF: benzo[b]fluoranthene BkF: benzo[k]fluoranthene BghiP: benzo[ghi]perylene IDP: indeno[123-cd]pyrene				

The results indicate that the levels across the soil types analysed (earthworks material and natural soils) were generally consistent. However, the levels of leachable PAH's are slightly above detection and higher within the earthworks material when compared to the natural soils.

Localised, marginally elevated levels were recorded for Benzo[k]fluoranthene (TP01), Benzo[ghi]perylene (TP11) and Indeno[123-cd]pyrene (TP11) with only 1 of 13 no. exceedances recorded for each determinant within the Made Ground. More exceedances were recorded for B(b)F and B(a)P, however the guideline for B(a)P is particularly stringent.

A statistical analysis has been carried out for the PAH results in the earthworks material and is discussed below.

Where elevated PAH values were recorded within earthworks materials, additional petroleum hydrocarbon testing was undertaken. The levels of TPH for most aliphatic and aromatic carbon banding were below the limit of detection with the exception of one low recorded elevated level (3.1 µg/l) of Aliphatic C16 - C21 in TP05 at 0.3m within the Fill A.

4.4.4 Statistical Assessment of Leachate Results

Elevated levels of PAHs were identified in the earthworks materials when compared to the UKTAG guideline values, and these have been assessed statistically in accordance with CIEH/CL:AIRE (2008). The analyses are presented as Appendix E and discussed below.

4.4.4.1 Benzo[a]pyrene (BaP)

The levels of BaP varied between <0.01 and 0.05 µg/l, with a sample mean of 0.02 µg/l and a standard deviation of 0.01 µg/l for a sample size of 13. The true mean (US95) is 0.03 µg/l.

The sample mean and true mean are above the stringent UKTAG value of 0.005 µg/l. No outliers are indicated and the distribution is normal.

4.4.4.2 Benzo[b]fluoranthene (BbF)

The levels of BbF varied between <0.01 and 0.12 µg/l, with a sample mean of 0.054 µg/l and a standard deviation of 0.03 µg/l for a sample size of 13. The true mean (US95) is 0.07 µg/l.

The sample mean and true mean is marginally above the UKTAG value of 0.05 µg/l however, no outliers are indicated and the distribution is normal.

4.4.4.3 Benzo[ghi]perylene (BghiP)

The levels of BghiP varied between <0.01 and 0.08 µg/l, with a sample mean of 0.03 µg/l and a standard deviation of 0.02 µg/l for a sample size of 13. The true mean (US95) is 0.04 µg/l.

The sample mean and true mean is below the UKTAG value of 0.05 µg/l and the distribution is normal. One sample from TP11 (0.4m) is indicated as an outlier, however the evidence level remained 100% without its removal.

4.4.4.4 Indeno[123-cd]pyrene (IdP)

The levels of IdP varied between <0.01 and 0.06 µg/l, with a sample mean of 0.02 µg/l and a standard deviation of 0.016 mg/kg for a sample size of 13. The true mean (US95) is 0.03 µg/l.

The true mean (US95) is 0.029ug/l.

The sample mean and true mean is below the UKTAG value of 0.05 µg/l and the distribution is normal. One sample from TP11 (0.4m) is indicated as an outlier, however the evidence level remained 100% without it's removal.

4.4.4.5 *Benzo[k]fluoranthene (BkF)*

The results of Benzo[k]fluoranthene (BkF) indicate that the sample mean is 0.024 µg/l, lower than the UKTAG value of 0.05 µg/l, with a standard deviation of 0.030 µg/l. The true mean (US95) is 0.06ug/l.

The sample mean is below the UKTAG value of 0.05 µg/l, however the true mean (US95) is slightly elevated.

A non-normal distribution is indicated and one outlier has been identified (TP01 – 4.4m). The evidence level is 90% with the inclusion of the outlier.

5 Discussion of Fill Nature and Chemistry

5.1.1 Earthworks Material Nature

As indicated by the Client, investigation on a 20 to 25m grid has confirmed that the earthworks fill does primarily consist of re-worked glacial and weathered bedrock soils. Two distinct layers have been encountered and this is likely due to two separate periods of fillings as the development progressed.

The soils generally contained rare to occasional, and generally inert man-made constituents including, brick, tarmac, fabric, plastic, metal and tile. The proportion of man-made materials was generally consistent across the site however, some areas contained locally more man-made components (e.g. TP08 and TP14). Fill B generally contained a higher proportion and greater variety of inert man-made materials when compared to Fill A.

The materials generally appeared to be inert building materials that had been incorporated into the natural soils from the neighbouring residential development.

Organic matter comprising partially decomposed grass, roots and branches was consistently encountered in pockets within Fill B (see Plate 10). This is likely associated with the historic vegetation and initial site clearance works.

5.1.2 Earthworks Material Contamination Status

5.1.2.1 Visual and In-situ Testing

No obvious visual or olfactory signs of contamination was identified within the earthworks materials (Fill A or Fill B).

PID headspace analysis was carried out on selected samples as discussed in Section 3.2 and low levels were recorded (below the detection limit to 0.3ppm).

5.1.2.2 Laboratory Testing - Soils

The laboratory testing has indicated that for the samples of earthworks materials (Fill A and Fill B), all determinands tested fell below the guideline values for public open spaces (residential). With the exception of localised PAH levels above detection (the majority were below), the recorded levels were generally in accordance with that of the underlying natural soils.

When compared to guidelines for residential properties, minor exceedances of Lead and Naphthalene were recorded in one position (TP14) however, statistical analysis (Section 4.3.5) indicates that there is sufficient evidence to demonstrate that the levels as a whole would have a low probability of posing a risk in this end use scenario.

The lead and naphthalene values in TP14 are outliers, however considering the general visual consistency of the materials, and the size of the sample population we consider them more likely representative of the upper bound levels.

In addition, previous laboratory testing of the in-situ glacial/shallow bedrock soils, identified naturally elevated levels of Lead. As such, the elevated levels of Lead in TP14 are considered to be consistent with the natural background levels of contamination..

5.1.2.3 Laboratory Testing - Leachate

The laboratory leachate testing has indicated that all levels of leachable metals were below the guideline values (or below detection limits) with some exceedances of leachable levels of PAH compounds identified. With the exception of the PAHs, which were slightly higher, the recorded levels were generally in accordance with that of the underlying natural soils.

When assessing the general groundwater quality (UK TAG), localised, elevated levels were recorded for Benzo[k]fluoranthene (TP01), Benzo[ghi]perylene (TP11) and Indeno[123-cd]pyrene (TP11) with only 1no. of 13no. exceedances recorded for each determinand within the fill material. More exceedances were recorded for Benzo[b]fluoranthene (5no.) and Benzo[a]pyrene (12no.), however the guideline for B(a)P is particularly stringent and below the limits of detection of current UK laboratory testing (0.01ug/l).

Statistical analysis has demonstrated that the true mean values are low, and are slightly below the guideline levels for I(123-cd)P and B(ghi)P and slightly elevated for B(a)P, B(k)F and B(b)F.

Outliers have been identified in TP01 (4.4m) for B(k)F and TP11 (0.4m) for I(123-cd)P and B(ghi)P which may indicate that a different sample population exists. However, visually the soils in these pits were consistent with the remainder of the site, there was no visual or olfactory evidence of contamination different to other pits and reference to the total soil levels indicate the determinants in question were below the limits of detection similar to the majority of other samples of the fill (with many other PAHs determinants below detection in the samples). We therefore consider it unlikely that they are representative of another sample population.

5.1.3 Natural Glacial Soils

The laboratory testing (Table 2 and Table 3) has indicated that for the samples of the natural Glacial Diamicton, all determinands tested fell below the guideline values for both public open spaces (residential). and residential with plant uptake.

The laboratory leachate testing (Table 4) has indicated that for the samples of the underlying natural Glacial Diamicton, all levels of leachable metals and most PAH compounds were below the guideline values (or below detection limits).

The levels of Benzo[a]pyrene are indicated to be above the guideline value, however, all results were below the limit of detection and do not necessarily pose a high risk to the groundwater beneath the site.

6 Assessment of the Chemical Suitability of the Phase 4 Fill Material

The following recommendations are based on interpretations made from the site investigation data obtained as part of the Local Authority (NPTCBC) agreed investigation strategy. The testing undertaken is considered robust and suitable to characterise the earthworks material placed at the site.

If at any stage of future construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a geo-environmental specialist sought immediately.

6.1 Risks to Health

6.1.1 Asbestos

No asbestos was detected within the fill materials and therefore at this stage no remedial recommendations in this regard are required for the material present in Phase 4.

If any ACM are encountered during future development, the advice of a suitably qualified specialist should be sought, and any identified ACM removed from site by a licensed specialist contractor.

6.1.2 Site End Users

6.1.2.1 Public Open Space (residential)

Assuming an end use of a for both public open spaces (residential), the identified levels of soil contamination within the fill materials at the site are not considered to pose a risk to future site users.

No specific remedial measures are considered necessary for the development.

6.1.2.2 Residential Properties with Gardens

As discussed in Section 1.1, there may be long-term potential for the Phase 4 plot of land to be developed as residential properties by the Client and as such the results of the laboratory testing have also been compared to guideline values for residential properties with plant uptake (Section 4.3.3).

Based on the testing and statistical analysis undertaken we consider the soils have a low probability of posing a risk to residential end users. However, should this end use be realised, we consider further check testing would be needed, including plot specific geo-environmental testing in the vicinity of TP14 to identify the extent of the elevated levels of lead and naphthalene encountered in this location.

Further remedial works may be required and appropriate measures would need to be taken prior to development to break the pollutant linkage and mitigate these risks in areas of soft surfacing (e.g. gardens, public landscaping etc.). Further advice can be sought by ESP should this be required.

6.1.3 Risk to Construction and Maintenance Workers

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks. However, we anticipate that the levels of contamination within the recent and historic fill are not likely to pose a severe acute risk to future construction workers or maintenance workers. Ground workers would need to undertake their own assessment of the risks to their workers.

We recommend that construction workers adopt careful handling of the potential contaminants and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation.

6.1.4 General Public/Neighbouring Properties

We do not anticipate any significant risks to the general public from the future development of the site. However, careful dust control measures should be adopted during any future construction to minimise the risk (and nuisance) to the general public and neighbouring residents.

6.2 Risks to Controlled Waters

In order to provide an assessment of the risk to controlled waters, samples of Made Ground as well as underlying natural glacial soils have been collected and scheduled for soil and leachate testing, Section 4.4.

No significant or olfactory evidence of contamination was identified during the investigation. Low levels of volatile hydrocarbons were recorded during PID headspace analysis (0.0 to 0.3ppm).

Total levels of soil contaminants tested were generally low, and generally below the most stringent residential human health acceptance criteria. Locally higher levels of PAH were noted within the fill material, however the majority of the levels were below the limit of detection.

The Level One assessment of risks to controlled waters has indicated that relative to groundwater standards, some exceedances of leachable levels of PAHs have been identified within the earthworks materials. However, the PAH guidelines are particularly stringent and statistical analysis indicates that the true mean values are very low.

The site lies within the area of Swansea/Neath valley which has an extensive history of industrial processes and as such, background levels of PAH contamination are commonly present in the shallow soils. We consider that the low levels of leachate identified locally within the fill material would be no greater than those in the shallow soils in the area, and therefore the potential contamination risk is not considered significant.

The underlying glacial soils are recorded as unproductive strata and were generally found to be fine grained or contain a high proportion of fines. Given the fine grained nature of the underlying glacial soils, it is likely that vertical migration of any leachate will be limited. The localised perched water bodies identified within the fill in the investigation confirm the lack of vertical migration.

The underlying Upper Coal Measures bedrock is classified as a Secondary A Aquifer, however it is also likely degraded due to the extensive underground mining in the area.

Based on the above, the controlled waters risks posed by the earthworks material placed by the Client in the Phase 4 area is considered to be low and we do not consider remedial action is warranted with regards to the earthworks fill.

6.3 Ground Gas

No formal assessment of the risks to future site users from hazardous ground gas has been undertaken.

For an end use of public open space the potential for risk is eliminated by the absence of enclosed spaces therefore no further consideration is required. However, should the site be considered for a future residential development, the following points are considered prudent:

- No significant amounts of organic matter was encountered within Fill A material;
- Organic matter (roots, branches and grass) was encountered in Fill B and could be a potential source of hazardous ground gas as it decomposes with time;
- If in the future, the site is considered for residential land use, further assessment will be required at that time and this may include gas monitoring.
- The presence of potentially elevated levels of methane, carbon dioxide and depleted oxygen in the Made Ground could pose a risk to construction workers, and lead to asphyxiation in confined spaces. All excavations should be treated as confined spaces and suitable precautions taken prior to man entry.
- If during future construction any organic materials are encountered they should be excavated and replaced.

7 Conclusions and Recommendations

As part of a wider construction project, site-won materials excavated from earlier phases (Phase 1 to 3) have been used to raise land levels at Phase 4. ESP were instructed to design and subsequently undertake a validation strategy to assess the chemical suitability of the material for the proposed end use (and potential future uses) and in the context of the environmental sensitivity of the area.

We consider the investigation and assessment undertaken, has been sufficient to demonstrate the chemical suitability of the Phase 4 material and that at this stage, no further investigation of the material is necessary.

If a residential end use is pursued in the future, we recommend check testing is undertaken to confirm the likely suitability of the soils. This should include targeted testing in the area of TP14.

The chosen geo-environmental consultant should also consider the ground gas source potential of the localised organic materials present in the lower portions of the fill with respect to end users and construction workers. If during future construction any organic materials are encountered they should be excavated and replaced.

If at any stage of future construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, it should be reviewed and the advice of a geo-environmental specialist sought immediately.

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