



Environmental

Site 5b, Clywedog Road South, Wrexham Industrial Estate

Geotechnical

Phase 1 Geo-Environmental Desk Study Assessment

For: FI Real Estate Management Ltd.

Highways

Structural

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1.0 INTRODUCTION

This Phase 1 Geo-Environmental Desk Study Assessment has been prepared at the request of FI Real Estate Management Ltd. Instructions to proceed with this report were received in September 2018.

The site encompasses an area of approximately 2.95 hectares and is located within Wrexham Industrial Estate; a large industrial area located approximately 4km to the east of Wrexham town centre. The national Ordnance Survey grid reference for the centre of the site is E337091, N349067 and the approximate post code is LL13 9XS.

The site is bound by mature trees and a small stream to the north, mature trees and an earthen bund to the east; beyond which lies a residential gardens and housing, densely vegetated open land to the south and Clywedog Road South to the west; beyond which lies a business park and several other commercial / industrial units.

It is the Clients intention to develop the site to include 2 No. new industrial units (one being portioned into 5 subsidiary units) with associated service yards, car parking and external hardstanding / soft landscaping areas.

Site location plans and an aerial photograph of the existing site can be found in Appendix 1.

The current proposed development plan is contained in Appendix 2. It should be noted this is not a finalised development plan and any change to the proposed development may require a reappraisal of this investigation.

2.0 **BRIEF**

The brief was to carry out a Phase 1 Geo-Environmental Desk Study Assessment for Site 5b, Clywedog Road South, Wrexham Industrial Estate, as shown on the aerial photograph and site plans contained in Appendix 1 and based upon the proposed development plan contained within Appendix 2.

The investigation was to include for the following studies:

- a) Assess the probable ground conditions and contaminated land conditions on and beneath the site, by undertaking a review of relevant desk study sources and by conducting a site walkover to establish the existing and historical on-site and relevant off-site activities.
- b) Using current contaminated land guidance to identify probable contaminants / sources of contamination, pathways and receptors that may be present at the site and develop a conceptual site model for potential human health, ground gas and controlled waters receptors.
- c) Undertake a Preliminary Risk Assessment to determine the requirement for further environmental (contaminated land) investigation and assessment.
- d) Based on the anticipated ground conditions design appropriate geo-environmental site investigation works and outline potential development issues (e.g. land / ground instability).

A detailed desk study report was to be provided to summarise findings and to provide recommendations.

3.0 LIMITATIONS OF INVESTIGATION WORK AND REPORT

Desk Study References

For the work, reliance has been placed on publicly available data obtained from the sources identified. The information is not necessarily exhaustive and further information relevant to the site may be available from other sources. When using the information, it has been assumed that it is correct. No attempt has been made to verify this information. New information, revised practices or changes in legislation may necessitate the re-interpretation of the report, in whole, or in part.

The desk study has been produced using historical Ordnance Survey maps and environmental maps available at the time the report has been produced. The environmental information used was the current information available at the time of writing but there is no absolute guarantee of accuracy.

Historical Ordnance Survey maps do not provide a comprehensive description of a site history. They provide details of the site from a date prior to the publication of the map (i.e. a snapshot in time). The period between map editions can be substantial (i.e. several decades). Not all map series are available for every date range in many areas of the UK and therefore there will be gaps in this mapped record for some sites. Potentially contaminative land uses could have been present and removed during such periods and may therefore not form a part of this particular record. In addition, there will be potentially contaminative land uses which are not identified on the map records such as small-scale storage / use of hazardous materials, illegal / unlicensed waste disposal activities etc.

Different map series identify different features utilising different symbols which can result in features that remain on site being removed from maps. Some features are also not mapped for security reasons (e.g. airfields and other military installations). These areas are mostly shown as blank areas on historical maps.

Site Walkover

During the site walkover, reasonable effort has been made to obtain an overview of the site conditions. However, during the site walkover no attempt has been made to enter areas of the site or its surrounds that are unsafe or present a risk to health and safety, are locked, barricaded, overgrown, or the location of the area has not been made known or accessible.

Exploratory Holes

Where the spacing of exploratory holes for future intrusive investigation work has been presented as part of this report, the spacing has been determined to provide a reasonable indication of the general ground conditions and extent of land / groundwater contamination on the site, but the number has ultimately been limited by commercial constraints. The findings from any exploratory holes are no absolute guarantee of the ground conditions and the extent of contamination between such locations. Due allowance should be made for the possibility of variation in conditions between exploratory hole locations.

Extent of Geo-Environmental Studies

This report is strictly limited to the nature of contamination contained within the ground and groundwater at the site. The report does not cover environmental aspects such as air or noise pollution and ground vibrations and the like. In addition, ecological matters relating to wildlife, flora and fauna have not been investigated as part of this report. In particular, the site has not been inspected for the presence or otherwise of invasive species (e.g. Japanese Knotweed). It is recommended that the Client appoints a specialist in this subject to carry out a detailed inspection / survey of the site if its presence is suspected. Where mention has been made to the identification asbestos or asbestos-containing materials this is for indicative purposes only and does not constitute or replace a full and proper survey. If an Unexploded Ordnance (UXO) report has been obtained within the report, it has been so on the basis of Health and Safety concerns and no assessment has been made other than

transcribing the recommendations of the sub-contractor contained within the report. In terms of a potential contaminative source, unless ordnance has been manufactured / stored on site, UXOs will only be determined as a contaminative source following a positive identification on site.

When investigating, or developing, potentially contaminated land it is important to recognise that sub-surface conditions may vary spatially and also with time. The absence of certain ground and / or groundwater conditions, ground gas, and contamination at the positions tested is not a guarantee that such conditions do not exist anywhere across the site.

Site sensitivity assessments have been made based on available information at the time of writing and are ultimately for the decision of the regulatory authorities.

Conclusions and Recommendations

The conclusions and recommendations sections of the report provide an overview and guidance only and should not be specifically relied upon without considering the context of the reporting in full. The conclusions resulting from this study are not necessarily indicative of future conditions or operating practices at or adjacent to the site.

4.0 THIRD PARTIES

This report has been prepared for the sole use of FI Real Estate Management Ltd. The report must not be copied or passed onto any third party or used for any purpose other than which it was prepared without the permission of the author. This report is copyright.

5.0 SCOPE OF WORK

5.1 Walkover Survey

The site was visited during partly cloudy and dry weather conditions and the objectives of the site walkover were, where applicable:

- to identify and assess visual and olfactory evidence of contamination (e.g. staining of concrete / soils, odours, presence of gas protection measures etc.);
- to identify locations of potential sources of contamination and assess their conditions (e.g. tank locations, presence / condition of secondary containment / bunds, location of fill points, process areas etc.);
- to identify surrounding land uses and any potentially contaminating activities;
- to identify / verify the presence of potential receptors (on and off-site) which may be affected by the identified sources;
- to obtain information on activities / procedures and standards of housekeeping etc;
- to assess site access and potential investigation locations and constraints;
- to assess any visual subsurface geotechnical features / anomalies (e.g. foundations, made ground, subsidence etc.).

Photographs were taken of the site during the walkover survey and these photographs, together with a plan indicating the location and direction of the photographs, are contained in Appendix 3.

5.2 Documentation

The following documents were either obtained and / or examined during the desk study works:

- a) An aerial photograph of the site dated 2017. This photograph is contained in Appendix 1.
- b) Historical Ordnance Survey maps as follows:

Date of Publication	Scale
1872	1:10,560
1872	1:2,500
1873	1:2,500
1898	1:10,560
1899	1:2,500
1909	1:10,560
1912	1:2,500
1938	1:10,560
1949	1:10,560
1960	1:2,500
1961	1:2,500
1964	1:10,560
1976	1:2,500
1978 x 2	1:2,500
1982	1:10,000
1984	1:2,500
1985	1:2,500
1986 x 2	1:2,500
1988	1:2,500
1989	1:2,500
1991 x 2	1:2,500
1992 x 2	1:2,500
1992	1:10,000
1992 x 2	1:2,500
1993 x 2	1:2,500
1994 x 2	1:2,500
2002	1:10,000
2010	1:10,000
2014	1:10,000

The historical maps obtained from Groundsure are contained in Appendix 4.

- c) The Groundsure EnviroInsight Report and associated maps were obtained in order to provide a list of recorded past and present activities, at or adjacent to the site, which could have an impact on the levels of contamination in the soils and groundwater at the site. This report is contained in Appendix 5.
- d) The Groundsure GeoInsight Report and associated maps were obtained in order to provide a list of recorded past and present activities, at or adjacent to the site, which could have an impact on ground stability. This report is contained in Appendix 6.
- e) Geo-Environmental maps, all dated 2018, obtained through Groundsure are as follows:
 - Historical Land Use map;
 - Environmental Permits, Incidents and Registers map;
 - Landfill and other Waste Sites map;
 - Current Land Use map;
 - Hydrogeology and Hydrology maps;
 - Environment Agency / Natural Resources Wales flood maps;
 - Designated Environmentally Sensitive Sites map;
 - Geological maps (1:10,000 and 1:50,000 scale);
 - Ground Workings map;
 - Mining, Extraction & Natural Cavities map;
 - Natural Ground Subsidence maps;
 - Borehole Records map;
 - Railways and Tunnels map.

These maps can be found alongside the Groundsure EnviroInsight and GeoInsight Reports contained within Appendix 5 and Appendix 6, respectively.

- f) The following British Geological Survey (BGS) maps were reviewed:

- BGS 1:50,000 and 1:63,000 series solid and drift maps for Wrexham (sheet reference: 121);
 - BGS 1:10,000 series solid and drift map for Wrexham (sheet reference: SJ34NE, dated 1996).
 - BGS 1:100,000 Mineral Resource Map for North East Wales (ref No: OR/10/022, dated 2010).
 - BGS 1:100,000 Aggregate Safeguarding Map for North East Wales (ref No: OR/12/029, dated 2012).
- g) 35 No. BGS borehole logs were also obtained (reference: SJ34NE42, SJ34NE49-67, SJ34NE68, SJ42NE69, SJ34NE70, SJ34NE71, SJ34NE72-73, SJ34NE45A-T, SJ34NE68 and SJ35SE7). Copies of the borehole logs are contained in Appendix 7.
- h) The following BGS Memoirs and BGS Reports were reviewed:
- Wedd, C B, Smith, B, Wills, L J, Lamplugh, G W. 1927. The Geology of the country around Wrexham: Explanation of one – inch geological sheet 121, new series. *Geological Survey of Great Britain*.
 - Hains, B A. 1991. Applied geological mapping in the Wrexham Area; geology and land use planning. *British Geological Survey Technical Report, WA/91/4*.
 - Waite, P J, Culshaw, M G, Hallam, J R. 1990. Engineering geology of the Wrexham Area. *British Geological Survey Technical Report, WN/90/10*.
- i) The Indicative Atlas of Radon in England and Wales published by the British Geological and the Health Protection Agency was examined to assess the probable presence or otherwise of radon gas in the ground. Extracts of the relevant maps are contained in Appendix 8.
- j) Previous site investigation works reviewed are as follows:

- GroundSolve Ltd. Coed Aben Road, Wrexham Industrial Estate, Proposed Industrial Unit, Phase I & II Geoenvironmental Report, December 2014 (Job Number: 1606).
- ESI Preliminary Risk Assessment: Former Firestone Site, Wrexham Industrial Estate, December 2012 (Report Reference: 60895R1).
- ESI Phase 2 Contaminated Land Investigation: Former Firestone Site, Wrexham Industrial Estate, December 2012 (Report Reference: 60895R2).
- BAE Systems, Property & Environmental Services, Desk Study for Potential Explosive Contamination at Wrexham Industrial Estate, February 2001 (Report Reference: A120-00-R1-A-DRAFT). This report was kindly provided by Wrexham County Borough Council through a freedom of information request.

The pertinent information from these reports is summarised in Section 6.14.

- k) Various Department of Environment (DOE) Industry Profiles were reviewed as part of the desk study works. The most pertinent being 'DOE Industry Profile – Chemical Works – Explosives, Propellants and Pyrotechnics Manufacturing Works'.
- l) Environment Agency, 2001. Land Contamination: Technical Guidance on Special Sites: Explosives Manufacturing and Processing Sites. R&D Technical Report P5 – 042/TR/03.
- m) A request for information pertaining to Royal Ordnance Factory (ROF) Wrexham was made to the Defensive Infrastructure Organisation (DIO). However, at the time of writing no reply has been forthcoming. If any pertinent information becomes available in the future than any necessary revisions will be made to this report.
- n) Valuable information pertaining to ROF Wrexham and the specific activities that were undertaken at the site were kindly provided via informal verbal

communication with Paul Harris of BAE Systems Ltd. An extract of the ROF Wrexham Historical Building Plan that covers the site was also kindly provided.

6.0 FINDINGS

6.1 Description of the Site

The site is irregular in shape and occupies an area of approximately 2.95 hectares and comprises densely vegetated open land with shrubs and mature trees along the sites eastern and northern boundary.

The site is relatively flat but there is a slight fall from approximately 37m Above Ordnance Datum (AOD) from the central northern section of the site to approximately 35.5m within the north easternmost section of the site and to approximately 34.5m within the southernmost section of the site.

The site is bound by mature trees and a small stream to the north, mature trees and an earthen bund to the east; beyond which lies a residential gardens and housing, densely vegetated open land to the south and Clywedog Road South to the west; beyond which lies a business park and several other commercial / industrial units.

Access to the site is easily obtained from the north western section of the site via a gate just off Clywedog Road South.

6.2 Walkover Survey

The walkover survey was carried out on the 31st October 2018 during partly cloudy and dry weather conditions. During the walkover survey the following features were noted relating to geology and contaminated land matters. For clarity, it is recommended that the site features plan contained within Appendix 9 is reviewed alongside this section.

During the walkover survey the following features were noted relating to geology and contaminated land matters:

Feature	Remarks
Site Access	➤ Access to the site can be obtained within the north western section of the site via a metal gate off Clywedog Road South.
Structures	➤ No structures were observed on-site.
Surface Cover	➤ The site is suspected to have been recently cleared of vegetation and at the time of the walkover comprised cleared vegetation with some grassed areas. ➤ No hardstanding areas were noted on-site.
Topography	➤ The site was noted to be relatively flat with a slight fall towards the south east. ➤ Grassed bunds elevated from typical site levels by approximately 0.5m were present adjacent to the sites north eastern and south eastern boundaries.
Ground Conditions	➤ The soil exposed at the surface comprised firm, dark brown, slightly sandy, silty CLAY. ➤ The ground was noted to be firm underfoot.
Obstructions	➤ No obstructions were noted during the survey.
Hydrogeology / Hydrology	➤ No surface water features were noted on-site at the time of the survey. ➤ 2 No small drainage channels (approximately 0.30m deep) were noted adjacent to the sites northern boundary and adjacent to the sites south easternmost section. All the drainage channels were noted to be dry at the time of the survey.
Evidence of Contamination / Potentially Contaminative Sources	➤ A few discarded tyres were noted in places across the site. ➤ A solvent odour was noted immediately to the north east of the sites north easternmost section, where some fly tipped materials that included a wellington boot, a trainer and a suspected cloth / towel were present. ➤ A blue plastic drum (unknown constituents) was noted within the vegetation that was present adjacent to the sites central eastern section. ➤ 2 No. blue plastic suspected chemical containers (approximately 5 – 10 litres) were noted in the drainage channel that was noted adjacent to the south easternmost section. A solvent odour was again noted in this area.
Trees	➤ Thickets of mature trees were located adjacent to the sites northern, eastern and south eastern boundaries.
Services	➤ A manhole was encountered immediately to the east of the sites southernmost section. ➤ A small culvert (approximately 200mm diameter) was encountered immediately to the south of the site and was noted to pass under Clywedog Road South.

Site Surrounds

Access could not be obtained to the land adjacent to the site but following an informal inspection the following observations were made:

Direction	Remarks
North	➤ The land immediately to the north of the site is occupied by a thicket of mature trees with a small drainage channel (noted above); beyond which lies a large warehouse (N U Instruments) with a car parking area. ➤ Further to the north east lies another large warehouse structure with service yard and car parking areas; belonging to the Tritch Group, who manufacture various products.
East	➤ The land immediately to the east of the site comprises a thicket of mature trees beyond which lies a number of residential gardens and properties.
South	➤ The land immediately to the south of the site comprises densely vegetated land with numerous thickets of mature trees. ➤ An electrical substation was noted approximately 110m to the south of the site.
West	➤ The land approximately 30m to the west of the site is occupied by Clywedog Road South beyond which lies several commercial properties and car parking areas belonging to Wilkinson Business Park. Several of the properties were noted to be vacant and up for let. An electrical substation also noted approximately 30m to the west of the sites northern section. ➤ A drainage channel runs parallel to Clywedog Road South and is culverted at several locations where access roads off Clywedog Road South were present. A flow to the south was noted during the survey. ➤ Immediately to the south of the Wilkinson Business Park and approximately 30m to the south east of the site is an industrial unit that houses several business. This includes Excel Signs, Apex Auto Centre and Lloyd and Jones Engineering Merchants. Access could not be obtained to these areas during the survey. ➤ Immediately to the north of Wilkinson Business Park and approximately 30m to the west of the sites northern section is a large warehouse operated by R F Bellis Haulage. A heavy goods vehicle yard was noted to the rear of this warehouse but access to this area could not be obtained. However, numerous heavy goods vehicles were noted. ➤ Immediately to the north of R F Bellies Haulage and approximately 30m to the north west of the site lies another warehouse operated by Wilsons Accident and Repair Centre. In addition to vehicle repairs, body and paint works were also noted to be undertaken. ➤ Immediately to the north of the Wilsons Accident and Repair Centre and approximately 70m to the north west of the site lies another warehouse operated by Malpas Tractors. Several new tractors were displayed in the yard. ➤ Immediately to the north of Malpas Tractors and approximately 100m to the north west of the site are 2 No. large warehouse structures belonging to Tension Control Bolts Ltd. a suspected light engineering works for the manufacture of tension control bolts.

Photographs were taken of the site during the walkover survey and these photographs, together with a plan indicating the location and direction of the photographs, are contained in Appendix 3.

A site features plan highlighting the majority of the above noted features is contained within Appendix 9.

6.3 Site History

The site development history has been researched by reference to historical maps and street plans. These are included in Appendix 4 to this report and the principal observations, which are summarised into on-site history and off-site history, are summarised below.

On-Site History

A detailed account of the site history can be found within the table below:

Dates	Site Features
1872	Since prior to 1872 most of the site is recorded as open fields / rural land. A north west to south east trending road (recorded as Ty'n-y-coed Lane by 1898) lined with trees crosses the central southern section of the site; a bench mark is also noted. A west to east trending footpath crosses the central section of the site and a small pond is recorded within the central north eastern section of the site. A north east to south west trending suspected hedgerow with trees is recorded within the southernmost section of the site.
1872 – 1898	Sometime between 1873 and 1898 the trees recorded alongside Ty'n-y-coed Lane and the hedgerow are no longer recorded. A second north to south trending footpath is recorded clipping the north western boundary of the site. This footpath branches off from the footpath that crosses the central section of the site.
1898 – 1899	Sometime between 1898 and 1899 a stream is recorded alongside the footpath that crosses the central section of the site. This stream may have been recorded on earlier maps but mapping at the relevant scale was not available for this section of the site. A suspected north east to south west footpath and / or stream is also recorded within the central south western most section of the site and terminates against Ty'n-y-coed Lane.
1938 – 1949	Sometime between 1938 and 1949 several rectangular structures are recorded across the site. A network of paths connects these buildings, with a main north to south east trending path running through the site.
1949 – 1960	Sometime between 1949 and 1960 some elongated mounds are recorded within the north westernmost section of the site. 2 No. hydrants are recorded within the northern section of the site; one being located close to the central section of the northern site boundary and the other being located within the central northern section of the site. 2 small rectangular structures are recorded within the central section of the site. Several possible drains are also noted to cross the site. A possible cutting is recorded alongside one of the paths within the central south western section of the site. The pond within the northern section of the site is also suspected to have been infilled during this time.
1960 – 1978	Sometime between 1964 and 1978 most of the structures and infrastructure (paths, hydrants, mounds) are no longer recorded; the exceptions being a single structure with infrastructure within the southernmost section of the site.
1978 – 1984	Sometime between 1982 and 1984 all of the structures and infrastructure at the site are no longer recorded.
1984 – 1989	Sometime between 1985 and 1986 a north east to south west trending elongated mound is recorded close to the sites north eastern boundary. Sometime between 1985 and 1989 a second north east to south west trending elongated mound is recorded close to the sites south eastern boundary. No significant changes are noted to the site.
1989 – 2010	Sometime between 2002 and 2010 the elongated mounds present close to the sites eastern boundary are no longer recorded. No significant changes are noted to the site.
2010 – 2014	No significant changes are recorded and the site is suspected to have remained derelict until the present day.

Off-Site History

Details pertaining to the off-site history and in particular those potentially contaminative and / or significant industrial land uses believed to be the most pertinent, based on their proximity to the site and their significance, are outlined in the table below:

Date	Features	Direction from Site	Distance from Site (approx.)
1938 – 1978	ROF Wrexham – recorded sometime between 1938 and 1949 and includes several structures (unrecorded use) associated with ROF Wrexham. Sometime between 1949 and 1960 also includes several mounds of unknown constituents. Sometime between 1964 and 1978 most of these structures and mounds are no longer recorded.	Various	0 – 500m
1872 – 1950	Infilled Ponds – numerous ponds recorded since prior to 1872. However, most of them are suspected to have been infilled (unknown constituents; potentially contaminative) sometime during the mid-20 th Century.	Various	20 – 250m
1989 – 2014	Wrexham Industrial Estate – numerous unlabelled buildings associated with Wrexham Industrial Estate are recorded sometime between 1989 and 1991. Further buildings are recorded sometime between 1992 and 1993 and sometime between 2002 and 2010. Most structures are present until at least 2014.	Various	30 – 250m
1938 – 2010	Mineral Railway – recorded sometime between 1938 and 1949. Sometime between 1964 and 1976 recorded as a dismantled railway. Sometime between 2002 and 2010 no evidence of this railway remains.	W	50m
1992 – 1994	Electrical Substation – recorded sometime between 1992 and 1993. Present until at least 1994	N	75m
1992 – 1994	Electrical Substation – recorded sometime between 1992 and 1993. Present until at least 1994	NNE	140m
1992 – 2014	Electrical Substation – recorded sometime between 1992 and 1993. Present until at least 2014.	NE	140m
1982 – 2014	Electrical Substation – recorded sometime between 1982 and 1986. Sometime between 2002 and 2010 no longer recorded. However, recorded again on the 2014 map so may still be present.	NE	190m
1992 - 2014	Suspected Works – recorded sometime between 1992 and 2002. Present until at least 2014.	SE	280m
1949 – 1982	Gravel Pit – recorded sometime between 1949 and 1964. No longer recorded sometime between 1964 and 1982.	SE	300m
1964 – 2014	Depot – recorded sometime between 1964 and 1982. Sometime between 2002 and 2010 has been enlarged. Present until at least 2014.	SE	310m
1964 – 2014	Works – numerous works buildings recorded sometime between 1964 and 1982. Sometime between 1982 and 1992 a significant expansion has occurred with an additional building being constructed. Sometime between 2002 and 2010 further minor expansions noted. Present until at least 2014.	SE	350m
1982 – 2014	Suspected Works – 2 No. suspected works buildings are recorded sometime between 1982 and 1992. Minor expansion and additional buildings added sometime between 1992 and 2002. Additional building added sometime between 2010 and 2014. Present until at least 2014.	SE	380m
1985 – 2014	Works – recorded sometime between 1982 and 1992. Present until at least 2014.	NE	390m
1899 – 1949	Tank – recorded sometime between 1898 and 1909. Sometime between 1938 and 1949 no longer recorded.	NE	400m

Date	Features	Direction from Site	Distance from Site (approx.)
1949 – 1992	Works – numerous works buildings recorded sometime between 1949 and 1960. Sometime between 1964 and 1982 has been enlarged. Sometime between 1982 and 1992 some structures are no longer recorded and the numerous works are now recorded as the Bridgeway Centre.	NE	500m
1964 – 2002	Factory (Firestone Tyre Manufacturing Facility) – recorded sometime between 1964 and 1982. Sometime between 1982 and 1992 has been enlarged. Sometime between 1992 and 2002 no longer recorded.	E	500m
1949 – 2014	Wrexham Industrial Estate – numerous Factories, Works, Depots and unlabelled structures associated with Wrexham Industrial Estate are recorded in the surrounding area sometime between 1949 and 1964. Continual growth and development is recorded until at least 2014.	Various	500 – 1000m

Those potentially contaminative sources outlined above are believed to be the most pertinent on the basis of their proximity to the site and their significance.

Since prior to 1872 and up until the mid-20th Century there were also a number of suspected farms within the surrounding area. Some of these farms persist until the present day.

Other potentially contaminative historical land uses and / or further details are recorded on the historical maps contained within Appendix 4 and within the Groundsure EnviroInsight Report contained within Appendix 5.

6.4 Geology

6.4.1 BGS Geological Maps

The BGS Geological Maps reviewed indicate that the site is underlain by Landscaped Ground, which is underlain by superficial deposits that comprise Devensian Till, which are in turn underlain by solid geology of the Salop Formation. It should be noted that River Terrace deposits are recorded approximately 50m to the south west of the site and may be present within the southernmost section of the site overlying the Devensian Till.

Further information pertaining to these strata and other pertinent geological information (e.g. faulting, structure and rock dip) are included within the table below:

Geological Feature	Details
Landscaped Ground	➤ Description: Refers to areas where the original topography has been extensively remodelled or re-shaped by earth-moving and tipping but where it is impracticable or impossible to delineate areas of Made Ground, Worked Ground or Disturbed Ground. Consequently, constituents are largely unknown but may be associated with the demolition of former ROF Wrexham and / or mining / quarrying waste and domestic / industrial refuse from within the surrounding area. ➤ Setting: Anthropogenic in origin and associated with historic on-site developments (e.g. the sites former use as a military site and landscaping of Wrexham Industrial Estate). ➤ Age: Mid to late 20th Century. ➤ Estimated Thickness: Unknown but could be significant in places such as at the location of backfilled structures or excavations.
Superficial Geology (Devensian Till)	➤ Description: Extremely variable in composition but typically comprises a firm to stiff or hard, reddish brown to dark brown, slightly gravelly, sandy CLAY with occasional beds / lenses of sand and gravel and interbeds of laminated clay / silt. The laminated clays are recorded as being very well developed at the Wrexham Industrial Estate. Often fissured, particularly within the upper few metres. Often displays a tripartite sequence of Upper Till, Middle Sands and Lower Till. ➤ Upper Glacial Till: Generally, a stoneless, red, calcareous CLAY with thin beds of sand and fragments of marine shells. In places may also comprise laminated clays as is indicated by its probable depositional environment (e.g. ice dammed waters of the Cheshire Lake). ➤ Middle Sands: Typically, discontinuous deposits of SANDS and SILTS with marine shells, often of no great thickness. These deposits probably represent re-sorted glacial material deposited in a lake as the ice-front melted. ➤ Lower Glacial Till Details: Typically, hard, red, occasionally grey TILL (chiefly boulder CLAY) containing numerous stones, often of considerable size. Marine shells may also be present. ➤ Permeability: Low to high permeability with flow dominantly through lenses / interbeds of sand and gravel. ➤ Setting: Glaciogenic in origin. They are detrital, created by the action of ice and meltwater and can form a wide range of deposits and geomorphologies associated with glacial and inter-glacial periods during the Quaternary. ➤ Age: Devensian Stage (approximately 11,500 to 116,000 years ago). ➤ Estimated Thickness: Approximately 40m thick.

Geological Feature	Details
Superficial Geology (River Terrace Deposits)	➤ Description: Predominantly sands and gravels with some silty clay / clayey silt beds. ➤ Permeability: High to very high permeability; flow is through matrix. ➤ Setting: Post Glacial in origin. They are fluvial in origin and detrital, ranging from coarse to fine-grained and form beds and lenses of deposits reflecting the channels, floodplains and levees of a river or estuary (if in a coastal setting). ➤ Age: Quaternary. ➤ Estimated Thickness: Unknown but based on topography a limited thickness is envisaged.
Solid Geology (Salop Formation)	➤ Description: Typically, weak, purple, red, grey and brown, thinly bedded, MUDSTONE containing siltstone and shale interbedded with thin, moderately strong, reddish brown and grey, thinly bedded, fine grained, micaceous SANDSTONES. Thin conglomerate bands containing limestone and chert occur within the upper part of the unit. Some thin coal seams may be present. There are also several thin limestone beds and caliche in the lower part of the unit. The mudstones are very susceptible to weathering and are typically completely weathered to a soft to hard, silty CLAY to depths of between 1 – 3m below rockhead. ➤ Permeability: Generally low permeability, higher permeability (moderate) in fissured near-surface material; flow dominantly through discontinuities. ➤ Setting: These sedimentary rocks are fluvial in origin. They are detrital, ranging from coarse to fine-grained and form beds and lenses of deposits reflecting the channels, floodplains and levees of a river or estuary (if in a coastal setting) ➤ Age: Asturian Substage – Cisuralian Epoch (approximately 272 to 310 million years ago). ➤ Estimated Thickness: As it is overlain unconformably by younger rocks its original thickness is not known. However, based on nearby borehole data it is estimated to be <200m thick in the local area.
Structure	➤ The site lies on the shallow easternmost limb of a syncline that encompasses almost all the Denbighshire Coalfield to the west and which forms an embayment to the north western margin of the much larger synclinal Cheshire Basin to the east.
Faulting	➤ No faults are recorded on-site. ➤ A north east to south west trending fault is located approximately 410m to the north west of the site. This fault is suspected to downthrow to the north west but by an unknown amount.
Rock Dip	➤ No rock dip is recorded on-site. However, 2 No. rock dips are recorded within a similar geological setting to the site: ✓ A rock dip of 10° to the east is recorded approximately 5.9km to the north west of the site ✓ A rock dip of between 5 – 10° to the north east is recorded approximately 5.5km to the south west of the site. ➤ In consideration of the above and the conjectured outcrop positions within the vicinity of the site a relatively shallow dip to the east is envisaged for the site.
Linear Features (excluding faults)	➤ No linear features are recorded on-site.
Glacial Landforms	➤ Numerous Glacial Landforms are recorded within the surrounding area and this includes moraines, meltwater channels and lakes. The nearest is an Ice Dammed Lake Deposit which is located approximately 440m to the north west north west of the site (this feature is associated with Glaciolacustrine Deposits on the BGS 1:50,000 Maps). ➤ The site and its surrounds (Carboniferous and Triassic outcrops) were occupied by the Irish Sea Ice Sheet during the last ice age. As the ice sheet retreated it would have acted as a dam to drainage, which would have otherwise reached the Irish Sea. Consequently, the area formerly occupied by this ice sheet probably became the site of a lake that covered much of the area.

A digital copy of the BGS 1:10,000 geological map can be found within the GeoInsight report contained within Appendix 6.

6.4.2 BGS Borehole Logs

There is a single BGS Boreholes log available for the site. Several BGS Borehole logs were also reviewed from the surrounding area and from within a similar geological setting to that which is present at the site. Those believed to be the most pertinent and most indicative of the underlying stratigraphy beneath the site, along with those located on-site, are outlined within the table below:

Boreholes	Details	Typical Ground Conditions	Groundwater
SJ34NE70	This BGS Borehole is located on-site and pertains to a proposed sewer line undertaken in December 1981.	This borehole typically recorded the following sequence: ➤ FILL comprising soft, brown CLAY to a depth of 0.50m bgl underlain by; ➤ Firm to stiff, locally soft to firm around sand seams, brown CLAY with streaks of grey silt and occasional sandy seams to a depth of between 3.00m bgl, underlain by; ➤ Soft, saturated, brown, sandy SILT to a depth of at least 6.50m, where this exploratory hole was terminated.	Water was struck at depth of 3.00m. A moderate rate of inflow was noted.
SJ24NE69	This BGS Borehole is located approximately 15m to the east of the site and pertains to a proposed sewer line undertaken in December 1981.	This borehole typically recorded the following sequence: ➤ FILL comprising soft, brown CLAY with traces of tree roots to a depth of between 0.75m bgl underlain by; ➤ Firm to stiff, brown CLAY with streaks of grey silt and occasional sandy pebbles to a depth of 4.50m bgl, underlain by; ➤ Soft, saturated, brown, sandy SILT (running conditions noted) to a depth of at least 9.50m, where this exploratory hole was terminated.	Water was struck at depth of 3.50m. A moderate rate of inflow was noted.
SJ34NE68	This BGS Borehole is located approximately 50m to the north east of the site and pertains to a proposed sewer line undertaken in December 1981.	This borehole recorded the following sequence: ➤ FILL comprising soft, brown CLAY with streaks of black topsoil to a depth of 0.70m bgl, underlain by; ➤ Soft to firm, brown CLAY with streaks of grey silt to a depth of 3.80m bgl, underlain by; ➤ Very soft, moist, brown, clayey, gravelly SILT to a depth of 5.50m bgl, underlain by; ➤ Very loose, saturated, brown SAND with traces of coal (running conditions noted) to a depth of 11.00m bgl.	Water was struck at 4.80m bgl and a moderate rate of inflow was noted.
SJ34NE71	This BGS Borehole is located approximately 70m to the south of the site and pertains to a proposed sewer line undertaken in December 1981.	This borehole recorded the following sequence: ➤ FILL comprising 650mm of concrete on firm, brown clay with small pieces of brick to a depth of 1.40m bgl, underlain by; ➤ Firm, light brown, CLAY with softer silty layers to a depth of 1.90m bgl, underlain by; ➤ Soft, saturated, light greyish brown SILT to a depth of 2.60m bgl, underlain by; ➤ Medium dense, rounded, medium GRAVEL to a depth of 4.00m bgl, underlain by; ➤ Soft, saturated, brown SILT to a depth of 4.60m bgl, underlain by; ➤ Stiff, brown, silty CLAY to a depth of at least 5.00m bgl.	Water was struck at 2.40m bgl and a large rate of inflow was noted.
SJ34NE49-67	9 No. BGS Borehole Logs were reviewed for an area located approximately 70m to the north west of the site. These were undertaken in January 1993.	These boreholes typically recorded the following sequence: ➤ MADE GROUND comprising stiff, brown, organic in places CLAY to a depth of between approximately 0.70m to 1.50m bgl, underlain by ➤ Stiff, brown, silty CLAY with streaks of stiff, grey silt to a depth of between at least 3.50m and 5.00m bgl, where these exploratory holes were terminated.	No groundwater was encountered during the excavation of these exploratory holes.

Boreholes	Details	Typical Ground Conditions	Groundwater
SJ34NE72-73	2 No. BGS Borehole Logs were reviewed for an area approximately 260m to the south south east of the site and pertain to a proposed sewer line. These were undertaken in December 1981.	These boreholes typically recorded the following sequence: ➤ FILL comprising soft brown CLAY or brown sandy CLAY to a depth of between 0.80m and 0.95m bgl, underlain by; ➤ Firm, brown sandy CLAY or brown, silty CLAY with a few pebbles to a depth of 1.40m bgl, underlain by; ➤ Loose to medium dense, saturated, brown, clayey, medium GRAVEL to a depth of between 2.70m and 3.00m bgl, underlain by; ➤ Firm to stiff, brown CLAY with streaks of grey silt or stiff, brown, silty CLAY with thin seams of sand (from 4.40m bgl) and occasional pebbles to a depth of at least 5.00m bgl.	Water was struck at depths of between 1.65m and 1.70m bgl and a large rate of inflow was noted.
SJ34NE45A-T	18 No. BGS Borehole Logs were reviewed for an area located approximately 330m to the north east of the site. These were undertaken by Strata Surveys Ltd. and Veryard and Partners Consulting Engineers in 1984.	These boreholes typically recorded the following sequence: ➤ MADE GROUND comprising soft to stiff, brown, sandy CLAY with roots, gravel and brick rubble and to a lesser extent loose to medium dense, red, brick rubble in brown CLAY to a depth of between 0.25m and 2.00m bgl, underlain by; ➤ Very stiff, brown to reddish brown, fissured, laminated in places, slightly sandy, silty CLAY with a little fine gravel, grey inclusions and small pockets of fine sand to a depth of between 5.60m and 9.50m bgl, underlain by; ➤ Firm to stiff, soft in places, laminated, brown, very silty CLAY with layers and lenses of silt and fine sand to a depth of between 8.00m and 13.00m bgl, underlain by; ➤ Firm to stiff, laminated in places, brown, slightly sandy to sandy, silty to very silty CLAY with a little fine gravel to a depth of between 15.00m and 17.60m bgl, underlain by; ➤ Very dense, reddish brown, clayey, gravelly, medium SAND to a depth of 18.10m bgl.	2 No. water strikes were encountered at depths of between 5.50 – 6.50m bgl. 2 No. water strikes were encountered at depths of between 9.20 – 10.20m bgl and were noted to rise to depths of between 1.20 – 2.00m bgl over several days. A single water strike was recorded at a depth of 17.6m and was noted to rise to 2.00m bgl over several days.
SJ34NE42	This BGS Borehole is located approximately 910m to the east north east of the site and pertains to a MAU sand and gravel borehole log sunk by the Dee and Clwyd River Division.	This borehole recorded the following sequence: ➤ Hard, boulder CLAY to a depth of 37m bgl, underlain by; ➤ Running SAND to a depth of 51m bgl, underlain by; ➤ COBBLES to a depth of 51.3m bgl, underlain by; ➤ COBBLES and GRAVEL to a depth of 53m bgl, underlain by; ➤ Boulder CLAY to a depth of 58.2m bgl, underlain by; ➤ GRAVEL to a depth of 59.6m bgl, underlain by; ➤ Red SANDSTONE (suspected bedrock) to a depth of 60.5m bgl.	Groundwater levels were not recorded but running sand conditions indicate that groundwater was present.
SJ35SE7	This BGS Borehole is located approximately 1100m to the north east of the site and pertains to a borehole sunk by George Wimpey & Co. Ltd. in November 1950.	This borehole recorded the following sequence: ➤ FILL to a depth of 0.23m bgl, underlain by; ➤ Very stiff, blue, brown mottled, silty CLAY to a depth of 5.49m bgl, underlain by; ➤ Stiff, brown, sandy, silty CLAY to a depth of 7.01m bgl, underlain by; ➤ Very stiff, brown, laminated, silty CLAY to a depth of 9.45m bgl, underlain by; ➤ Firm, brown, sandy, silty CLAY with layers of brown medium sand to a depth of 11.58m bgl, underlain by; ➤ Brown, fine to medium SAND with thin layers of firm, brown, silty clay to a depth of 14.02m bgl, underlain by; ➤ Firm, brown, silty CLAY with layers of brown, fine to medium sand to a depth 19.81m bgl, underlain by; ➤ Brown, silty, fine SAND to depth of 21.64m bgl, underlain by; ➤ Very stiff, brown, laminated, sandy, silty CLAY to a depth of 24.69m bgl, underlain by; ➤ Brown, silty, fine SAND and GRAVEL to a depth of 30.18m bgl, underlain by; ➤ Stiff, brown, sandy, silty CLAY to a depth of 31.39m bgl.	Water under artesian pressure was encountered between 19.31 – 21.64m bgl and between 24.69 – 26.82m bgl, which caused water to rise up inside the borehole casing to 4.52m bgl and then resting at 1.52m bgl.

For exceptions to the above noted typical ground conditions please refer to the individual BGS Borehole Logs contained within Appendix 7.

6.5 Ground Stability

The maximum hazard ratings provided by the BGS Geosure Data, that is included within the Groundsure Reports, has been summarised in the table below:

Hazard	Location	Geosure Hazard Rating
Shrink Swell	On-site	Very Low
Soluble Rocks	On-Site	Negligible
Compressible Ground	On-Site	Negligible
Collapsible Ground	On-Site	Very Low
Running Sand	On-Site	Negligible
Landslides	On-Site	Very Low

Further details pertaining to the ground stability data can be found within the Groundsure Reports and associated maps contained within Appendices 6 and 7. An independent geotechnical risk assessment can also be found in Section 7.9.

6.6 Mining or Mineral Extraction

The site lies within a Coal Authority Coal Mining Reporting Area and numerous other types of mining are known to have occurred in the Wrexham District. Consequently, numerous desk study sources were reviewed to ascertain if the site has been subject to any historical and / or current mining activity that is recorded to have occurred in the area. The principal findings have been outlined in the table below:

Mining Type	Likely Sources in the Wrexham District	Details	Risk
Sand and Gravel	Glacial Sand and Gravel River Terrace Deposits	➤ Sand and gravel has been worked in the past and is currently being worked for building and other purposes. ➤ Numerous former and current sand and gravel pits are record within the district but these are largely confined to the Glacial Sand and Gravel and River Terrace Deposits that are noted to outcrop at or close to the surface. ➤ A gravel pit is recorded approximately 300m to the south east of the site on the historical maps. It is unknown if this pertains to mineral workings or pertains to an excavation of some kind associated with the nearby works buildings. ➤ Large areas of potentially workable sand and gravel resources that may be used in the future are present within the district but the site does not lie within one of these areas. However, thick deposits of sands and gravels may be present beneath the Glacial Till that is recorded on-site. ➤ The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Low
Brick Clay (including fireclay)	Ruabon Marl Formation, Coal Measures, Salop Formation and Devensian Till	➤ Clay rich deposits have been extensively worked within the district for brickmaking, tiles and other earthenware products. However, there is limited evidence from historical mapping of any clay pits / brick pits on-site or within the surrounding area; although a brick works is noted approximately 610m to the north east of the site. ➤ Fireclays (the seatearths underlying most coal seams) were often worked alongside the coal for use as a refractory material but the site is not recorded to be in an area where coal mine workings have occurred. ➤ Those solid geological units worked for clay are unlikely to have been worked beneath the site as they are located beneath thick drift deposits or are located at depths <300m beneath the site. ➤ The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded. ➤ The Groundsure GeoInsight states that there are no clay mining areas within 1000m of the site.	Low
Coal Mining	Coal Measures	➤ The site lies within a designated Coal Authority Coal Mining Reporting Area. ➤ Coal Measures rocks are present beneath the site but at depths <400m beneath the site so unrecorded workings (e.g. bell pits and outcrop workings) are highly unlikely. ➤ Thin coal seams are recorded to be present within the Salop Formation but these are not recorded to have been worked and unrecorded workings are unlikely due to the presence of thick drift deposits. ➤ The site is not located within an area where underground coal mine workings are recorded to have occurred. The nearest underground works are recorded approximately 1.5km to the west of the site. ➤ There are no recorded mine entries located on-site. ➤ Reserves of coal exist beneath the site that may be worked in the future.	Very low

Mining Type	Likely Sources in the Wrexham District	Details	Risk
Road Metal	Devensian Till, Cefn-Y-Fedw Sandstone, Wenlock and Ludlow Shales, Carboniferous Limestone	- Numerous deposits were locally worked for road metal and this included boulders within the natural superficial deposits which were blasted and carted to the requisite spots on the roadsides. - Except for those boulders contained within the natural superficial deposits most of the economic deposits are located beneath a thick cover of drift or located at depths <700m beneath the site. Consequently, they are highly unlikely to have been worked. - The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Very low
Iron Ore	Coal Measures and Carboniferous Limestones	- Iron ore in the form of nodules and, less commonly, thin layers of siderite, are widespread throughout the Coal Measures Formations and were worked extensively in the 19th Century alongside coal mine workings. - Haematite deposits also occurred within the Carboniferous Limestones near Dingle. These were first quarried and then a large underground gallery was driven along the deposit. - Iron ore bearing strata within the Coal Measures are located at depths <400m beneath the site so unrecorded workings (e.g. bell pits and outcrop workings) are highly unlikely. - The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Negligible
Lime and Limestone (including chert)	Carboniferous Limestone (Cefn Mawr, Minera Formation and Loggerheads Limestones)	- In the past the Carboniferous Limestone was extensively worked from quarries for agricultural lime and as a flux for iron smelting and to a very limited extent, chert for glass making. Currently they are worked for aggregates and the cement industry. - Economic deposits of Carboniferous Limestone outcrop approximately 10km to the west of the site and are located at depths <1000m beneath the site. - Thin limestone beds are present within the Salop Formation that is present beneath the site but these are too thin to have been of any value and are located beneath thick drift deposits. - The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Negligible
Sandstone	Minera Formation, Kalkyn Formation and Coal Measures Sandstones (Cefn Rock)	- Quartzitic and feldspathic sandstones within the district have been widely exploited in the past for silica brick making, roadstone, building stone and potentially for use as aggregate. - Economic sandstone deposits are unlikely to have been worked beneath the site as they are located beneath thick drift deposits and at depths <400m. - The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Negligible
Bedrock Sand and Gravel	Sandstones within the Carboniferous Limestones, Triassic Sandstone and Cefn-Y-Fedw Sandstone	- Sand and gravel has been worked in the past and is currently being worked for building and other purposes. - Economic sandstone deposits of bedrock sand and gravel are unlikely to have been worked beneath the site as they are located beneath thick drift deposits, at depths <700m or the solid geology postdates the deposits that are present on-site (e.g. Triassic Sandstones). - The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Negligible
Slate	Pen-Y-Glog Group and Pentre-dwfr Slates	- Extensively worked within the district for roofing slate. - Economic deposits outcrop approximately 17km to the south west of the site and workings are restricted to this area.	Negligible
Metalliferous Mining (lead, zinc and copper ores)	Carboniferous Limestones and Cefn-y-fedw Sandstone	- Metalliferous mining was restricted to mineral lodes present within an area approximately 10km to the north east of the site. - These mineral lodes are primarily associated with specific faults (e.g. Bala Fault System) and other nearby faults so they are highly unlikely to be present within the Carboniferous Limestones that are present beneath the site at depths <1000m. - The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Negligible

Mining Type	Likely Sources in the Wrexham District	Details	Risk
Barytes	Carboniferous Limestones and Ludlow Shales	➤ Barytes veins have been intermittently worked by means of opencast workings, day levels and shafts and was restricted to an area approximately 10km to the west of the site. ➤ The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded.	Negligible
Brine Extraction	Wilkesley Halite Member	➤ The site lies outside of the Cheshire Brine Subsidence Compensation area and outside of a brine extraction area. ➤ The site does not lie within or within 1000m of a BGS Non-Coal Mining area or an area where non-coal mining cavities are recorded. ➤ Salt bearing strata are not present beneath the site as the solid geology postdates most of the Triassic salt deposits. ➤ Wet rockhead is recorded near Whitchurch which is located approximately 18km to the south east of the site.	Negligible

Further details pertaining to the mining or mineral extraction data can be found within the Groundsure GeoInsight Report and associated maps contained within Appendix 6.

6.7 Hydrology and Hydrogeology

The principal observations relating to hydrology and hydrogeology obtained from the available desk study sources are outlined in the table below:

Data Type	Location*	Details
Aquifer within Superficial Deposits	On-site	➤ The natural superficial deposits (Devensian Till) beneath the site are classed as a Secondary Undifferentiated Aquifer. ➤ The River Terrace Deposits recorded approximately 50m to the south west of the site are classified as a Secondary A Aquifer.
Aquifer within Bedrock Deposits	On-site	➤ The solid geology (Salop Formation) beneath the site is classified as a Secondary A Aquifer.
Groundwater Abstraction Licenses	Off-site	➤ There are no recorded groundwater abstraction licenses located on-site. ➤ There are 9 No. groundwater abstraction licenses within 2km of the site. The nearest are located approximately 1010m to the east of the site and pertain to groundwater extracted from a borehole for process water. The licenses are historical with an annual volume of 131400m³. ➤ The remaining groundwater abstraction licenses also pertain to process water.
Surface Water Abstraction Licenses	Off-site	➤ There are no recorded surface water abstraction licenses located on-site. ➤ There is a single surface water abstraction license located within 2km of the site. This is located approximately 1467m to the north east of the site and pertains to surface water extracted from a tributary of the Redwither Brook for non – evaporative cooling. This is a historical license with an annual volume of 9955.74m³.
Potable Water Abstraction Licenses	N/A	➤ There are no recorded potable water abstraction licenses located on-site. ➤ There are no potable water abstraction licenses within 2km of the site.
Source Protection Zones	Off-site	➤ There are no Source Protection Zones located on-site. ➤ A Source Protection Zone 3 is located approximately 461m to the north of the site. ➤ There are no Source Protection Zones within Confined Aquifers within 500m of the site.
Groundwater Vulnerability and Soil Leaching Potential	On-site	➤ The site is classified as a Minor Aquifer with High Leaching Potential (HU) due to the presence of artificial ground that is assumed to be of high permeability due to the lack of site-specific information.
River Quality	Off-site	➤ There are 2 No. Biological River Quality data points within 2km of the site. These are located approximately 987m to the south west of the site and pertain to the River Clywedog (dee). From 2005 to 2009 the Biological Quality Grade has been recorded as B. ➤ There are 4 No. Chemical River Quality data points within 2km of the site. The nearest are located approximately 551m to the south west of the site and pertain to the River Clywedog. From 2005 to 2009 the Chemical Quality Grade has been recorded as B. The other data points also pertain to the River Clywedog also with a Chemical Quality Grade B.
Surface Water Features	Off-site	➤ There no surface water features located on-site. ➤ There are 13 No. surface water features located within 250m of the site. The nearest pertains to a small stream / drain located approximately 9m to the south east of the site. The remainder pertain to small streams / drains that all lie within the catchment area of the River Dee.
Flooding	Off-site	➤ The site is located within a Flood Zone 1 and the highest risk of flooding is recorded as very low. ➤ A Flood Zone 2 is recorded 207m to the south of the site. ➤ A Flood Zone 3 is recorded 248m to the south east of the site.
Flood Defences	N/A	➤ There are no recorded Flood Defences within 250m of the site.

Data Type	Location*	Details
Areas Benefiting from Flood Defences	N/A	➤ There are no areas benefiting from flood defences within 250m of the site.
Areas Benefiting from Flood Storage	N/A	➤ There are no areas benefiting from flood storage within 250m of the site.
Groundwater Flooding Susceptibility Areas	Off-site	➤ There is a BGS groundwater flooding susceptibility area within 50m of the site. This pertains to clearwater flooding or Superficial Deposit Flooding and there is the potential for this to occur at the surface. The level of confidence in this result is considered to be moderate.

* **Red** = onsite, **Orange** = within 250m of the site, **Yellow** = within 500m of the site, **Green** = greater than 500m from the site

Additional features and further details can be found within Groundsure EnviroInsight Report and associated maps that are contained in Appendix 5.

6.8 Environmental Permits, Incidents, Registers and Hazardous Substances

The principal observations relating to environmental permits, incidents, registers and hazardous substances obtained from the available desk study sources are outlined in the table below:

Data Type	Location*	Details
Records of Historic IPC Authorisations	Off-site	➤ There are 3 No. Historic IPC Authorisations within 500m of the site. All of these are located approximately 427m to the east of the site and pertain to non-ferrous metals. The most recent was issued to Hydro Aluminium Deeside Ltd. in November 1998 but has since been revoked and is now an IPPC.
Records of Part A (1) and IPPC Authorised Activities	Off-site	➤ There are 48 No. records of Part A (1) and IPPC Authorised Activities within 500m of the site. All are located approximately 427m to the east of the site and pertain to an aluminium works. Processes include melting with capacity >4t/D Lead / Cadmium or 20t/D others, melting with capacity =>5t, melting including making alloys, of non-ferrous metals, including recovered processes.
Records of Red List Discharge Consents	N/A	➤ There are no records of Red List Discharge Consents within 500m of the site.
Records of List 1 Dangerous Substances Inventory	N/A	➤ There are no records of List 1 Dangerous Substances Inventory within 500m of the site.
Records of List 2 Dangerous Substances Inventory	N/A	➤ There are no records of List 2 Dangerous Substances Inventory within 500m of the site.
Records of Part A (2) and Part B Activities	Off-site	➤ There are 3 No. records of Part A (2) and Part B Activities recorded within 500m of the site. The nearest of which is located approximately 302m to the south east of the site and pertains to Lloyds Animal Feeds that undertakes coating processes. ➤ Others Part A (2) and Part B Activities pertain to non-ferrous metal foundry processes and di-isocyanate processes.
Records of Category 3 or 4 Radioactive Substances Authorisations	N/A	➤ There are no Radioactive Substances Authorisations located within 500m of the site.
Licensed Discharge Consents	Off-site	➤ There are 5 No. licensed discharge consents located within 500m of the site. The nearest of which is located approximately 487m to the south of the site and pertains to an unspecified effluent type that discharges to the River Clywedog. It became effective in May 1982 and has yet to be revoked. ➤ Other licensed discharge consents also pertain to unspecified effluent types that discharge to streams near Redwither Brook and to the River Clywedog.
Records of Water Industry Referrals	N/A	➤ There are no records of Water Industry Referrals within 500m of the site.
Records of Planning Hazardous Substance Consents and Enforcements	N/A	➤ There are no records of Planning Hazardous Substance Consents and Enforcements within 500m of the site.
Records of COMAH and NIHHS Sites	N/A	➤ There are no COMAH or NIHHS sites located within 500m of the site.

Data Type	Location*	Details
Pollution Incidents	Off-site	➤ There 8 No. pollution incidents (List 2) recorded within 500m of the site. The nearest of which is located approximately 239m to the east of the site and pertains to atmospheric pollutants and effects. This incident is classified as Category 4 (No Impact) for waters, Category 4 (No Impact) for land and Category 3 (Minor) for air. Other pollution incidents pertain to waste materials (other), agricultural materials and wastes (slurry and dilute slurry), other pollutants (noise and other) pollutant not identified. ➤ There are no records of pollution incidents (List 1) recorded within 500m of the site.
Sites Determined as Contaminated Land under Part 2A SPA 1990	N/A	➤ There are no records of sites determined as Contaminated Land under Part 2A SPA 1990 within 500m of the site.

* **Red** = onsite, **Orange** = within 250m of the site, **Yellow** = within 500m of the site, **Green** = greater than 500m from the site

Additional features and further details can be found within Groundsure EnviroInsight Report and associated maps that are contained in Appendix 5.

6.9 Landfill and Other Waste Sites

The principal observations relating to landfill and other wastes obtained from the available desk study sources are outlined in the table below:

Data Type	Location*	Details
Environment Agency / Natural Resource Wales Landfill Data	N/A	➤ There are no Environment Agency / Natural Resource Wales landfills within 1000m of the site.
Environment Agency / Natural Resource Wales Historic Landfill Sites	Off-site	➤ There are 4 No. Historic Landfill Sites recorded within 1500m of the site. The nearest of which is located approximately 978m to the north east of the site and pertains to industrial and liquid sludge. The license holder was British Celanese Ltd. First recorded in December 1953 and last recorded December 1983. ➤ The other Historic Landfill Sites pertain also pertain to industrial and liquid sludge and are suspected to be associated with the above.
BGS / Doe Non-Operational Landfill Sites	N/A	➤ There are no BGS / Doe Non-Operational Landfill Sites within 1500m of the site.
Local Authority Historic Landfill Sites	N/A	➤ There are no Local Authority Historic Landfill Sites located within 1500m of the site.
Waste Treatment, Transfer or Disposal Sites	N/A	➤ There are no Waste Treatment, Transfer or Disposal Sites located within 500m of the site.
Environment Agency / Natural Resource Wales Licensed Waste Sites	Off-site	➤ There are 48 No. Environment Agency / Natural Resource Wales Licensed Waste Sites recorded within 1500m of the site. The nearest of which is located approximately 945m to the south west of the site at Abenbury Biological Treatment Facility with a size of < 25000 tonnes. The operator is United Utilities Green Energy Limited and the license was effective April 1995 and has been surrendered. ➤ Other Environment Agency / Natural Resource Wales Licensed Waste Sites pertain to biological treatment facilities, special waste transfer stations, material recycling treatment facilities, metal recycling (vehicle dismantler), household, commercial and industrial wastes, landfill gas engine, chemical treatment facilities, physical treatment facility, clinical waste transfer station and unknown.

* **Red** = onsite, **Orange** = within 250m of the site, **Yellow** = within 500m of the site, **Green** = greater than 500m from the site

Additional features and further details can be found within Groundsure EnviroInsight Report and associated maps that are contained in Appendix 5.

6.10 Current Industrial Land Use

The principal observations relating to current industrial land uses obtained from the available desk study sources are outlined in the table below:

Data Type	Location*	Details
Current Industrial Data	Off-site	➤ There are 24 No. Current Industrial Data points within 250m of the site. The nearest of which is located approximately 29m to west of the site and pertains to an electrical feature. ➤ Other pertinent features pertain to electrical features, transport storage and delivery, foodstuffs, industrial products, repair and servicing, infrastructure and facilities, industrial products and industrial features.
Petrol and Fuel Sites	N/A	➤ There are no petrol or fuel site located within 500m of the site.
National Grid High Voltage Underground Transmission Cables	N/A	➤ There are no records of National Grid High Voltage Underground Transmission Cables within 500m of the site.
National Grid High Pressure Gas Transmission Pipelines	N/A	➤ There are no records of National Grid High Pressure Gas Transmission Pipelines within 500m of the site.

* **Red** = onsite, **Orange** = within 250m of the site, **Yellow** = within 500m of the site, **Green** = greater than 500m from the site

Additional features and further details can be found within Groundsure EnviroInsight Report and associated maps that are contained in Appendix 5.

6.11 Sensitive Land Uses

The principal observations relating to sensitive land uses obtained from the available desk study sources are outlined in the table below.

Data Type	Location*	Details
Sites of Special Scientific Interest	N/A	➤ There are no Sites of Special Scientific Interest within 2km of the site.
National Nature Reserves	N/A	➤ There are no National Nature Reserves within 2km of the site.
Special Areas of Conservation	N/A	➤ There are no Special Areas of Conservation within 2km of the site.
Special Protection Areas	N/A	➤ There are no Special Protection Areas within 2km of the site.
RAMSAR	N/A	➤ There are no RAMSAR sites within 2km of the site.
Ancient Woodland	Off-site	➤ There are 51 No. Ancient Woodland sites within 2km of the site. The nearest of which is located approximately 244m to the north east of the site and pertains to an unknown ancient and semi-natural woodland.
Local Nature Reserves	N/A	➤ There are no Local Nature Reserves within 2km of the site.
World Heritage Sites	N/A	➤ There are no World Heritage Sites within 2km of the site.
Environmentally Sensitive Areas	N/A	➤ There are no Environmentally Sensitive Areas within 2km of the site.
Areas of Outstanding Natural Beauty	N/A	➤ There are no Areas of Outstanding Natural Beauty within 2km of the site.
National Parks	N/A	➤ There are no National Parks within 2km of the site.
Nitrate Sensitive Areas	N/A	➤ There are no Nitrate Sensitive Areas within 2km of the site.
Nitrate Vulnerable Zone	N/A	➤ There are no Nitrate Vulnerable Areas within 2km of the site.
Green Belt Land	Off-site	➤ There are no areas of Green Belt Land within 2km of the site.

* **Red** = onsite, **Orange** = within 250m of the site, **Yellow** = within 500m of the site, **Green** = greater than 500m from the site.

Additional features and further details can be found within Groundsure EnviroInsight Report and associated maps that are contained in Appendix 5.

6.12 Radon

The Indicative Atlas of Radon in England and Wales produced by the Health Protection Agency and British Geological Survey indicates that the site lies within a Radon Area where between 3 – 5% of homes are above the action level. Consequently, BR211 (2015) indicates that basic radon protective measures are necessary.

Map 13 of the Indicative Atlas of Radon in England and Wales and BR211 (2015) is contained within Appendix 8.

6.13 Consultations

Invaluable information pertaining to ROF Wrexham and the specific activities that were undertaken at the site were kindly provided via verbal communication with Paul Harris of BAE Systems Ltd. An extract of the ROF Wrexham Historical Building Plan that covers the site was also kindly provided by Paul Harris and permission was granted to include this extract within this desk study report.

Indicative information obtained from this informal consultation has been summarised below:

- The manufacture of Cordite at ROF Wrexham was undertaken in a systematic manner with specific areas being designated to specific processes within the production cycle.
- Raw materials were delivered within the north easternmost section of ROF Wrexham, with the most potentially contaminative processes generally being undertaken within the north eastern section.
- The finished product was then loaded directly onto trains within the south westernmost section of ROF Wrexham, with the least potentially contaminative processes generally being undertaken within the south western section.
- The site itself is located in an area of the base that was towards the end of the production cycle with those structures located on-site in use as blending houses where different batches of cordite were mixed together to maintain a consistent product.
- The larger structures to the north east of the site were the drying houses used to remove / recover acetone and any inadequately-blended nitroglycerine from the finished cords. The structures were heated by radiators, with a fume extraction system to remove the acetone. The cords were laid down in these rooms and the fumes were condensed and then distilled into tanks to recover and recycle the acetone. The acetone tanks were then transported by tankers to those areas of the base where the earlier stages of the production cycle were undertaken.

- The structures to the north of the site included the shifting buildings where workers changed clothes at the start or end of their shift and the various buildings associated with the loading of the finished product onto rail transport.
- Numerous underground pipes would have led from each building to transfer process effluent etc. to various parts of the site. This is confirmed on the historical building plan extract provided, that indicates that process effluent, fire and regular domestic pipes were present beneath the site.
- At the blending houses contamination can arise from reject cordite being discarded during packaging and fragments of cordite being swept into drainage systems or being swept outside of buildings directly to the soil.
- Overall, as the site was located within an area of the base that was towards the end of the production cycle the contaminative potential from any potentially explosive contaminants was considered to be low. However, localised contamination may be present within drainage if it remained intact following the landscaping that is recorded to have occurred.
- Demolition waste may also be contaminated with Nitroglycerine as it is particularly prone to contaminating porous surfaces such as building fabric.
- Asbestos within the soils from the demolition of the on-site structures was also considered to be likely.

An extract of the ROF historical building plan is contained within Appendix 10.

6.14 Previous Site Investigations

Details pertaining to previous site investigation works undertaken at the site and its immediate surrounds are outlined in the table below:

Reports Reviewed as part of the Desk Study Works		
Title	Date	Reference
BAE Systems, Property & Environmental Services, Desk Study for Potential Explosive Contamination at Wrexham Industrial Estate	February 2001	A120-00-R1-A-DRAFT
GroundSolve Ltd. Coed Aben Road, Wrexham Industrial Estate, Proposed Industrial Unit, Phase I & II Geoenvironmental Report	December 2014	1606
ESI Preliminary Risk Assessment: Former Firestone Site, Wrexham Industrial Estate	December 2012	60895R1
ESI Phase 2 Contaminated Land Investigation: Former Firestone Site, Wrexham Industrial Estate	December 2012	60895R2

Pertinent information from these reports has been summarised on the following pages.

I. BAE Systems, Property & Environmental Services, Desk Study for Potential Explosive Contamination at Wrexham Industrial Estate

A detailed desk study was undertaken by BAE Systems for an area approximately 930m to the north east of the site in February 2001.

The report contained detailed information regarding ROF Wrexham and BAE Systems comments have been summarised below:

Section	Details
History	➤ Planning of the site commenced in May 1939 and initially the factory was to be a duplicate of the 3 cordite production units located at ROF Bishopton. However, only 2 units were ever constructed at ROF Wrexham due to a lack of labour. ➤ Following numerous disputes regarding the sites eventual location approval to proceed with the construction of ROF Wrexham was given at the end of August 1939. ➤ Construction was expected to take 18 months from the date of approval but the second unit took longer to build than the first as some of the labour force were transferred to start work within the first unit. ➤ By December 1940 there were 500 people producing cordite at ROF Wrexham and production had reached approximately 480 tons a week. The two units had initially been planned to produce only 130 tons a week. By this time the prospect of a third unit had been abandoned and the plant was transferred to Irvine, Scotland. ➤ ROF Wrexham became operational in February 1941, just over a year after the start of construction. ➤ In 1942 increased production was gained by installing an acid plant from Huddersfield. The maximum recorded production at ROF Wrexham was 520 tons per week and this was maintained for a short while until production halved shortly afterwards. By January 1942 the total number of workers employed at ROF Wrexham was 6095. ➤ Operation of ROF Wrexham ceased on 11th August 1945. ➤ Royal Ordnance Propellant Division conducted an inventory of capital assets for all propellant factories between 1945 and 1946. Unfortunately, BAE systems state that the records pertaining to ROF Wrexham are incomplete and only a limited list of building usage is recorded. ➤ Ministry of Defence Sources (MOD) indicate that following the decommissioning of the site, certain areas of ROF Wrexham, specifically the guncotton plants, were potentially contaminated by small quantities of explosives in the drainage systems and floors of buildings. BAE Systems state that it is reported that remediation work was conducted in these areas but no records could be obtained regarding these works. ➤ Shortly after closure the site was sold for redevelopment as an Industrial Estate, with the current Wrexham Industrial Estate being established sometime during 1946.
Cordite Manufacture	➤ The two cordite production units at ROF Wrexham were built specifically for the production of solventless cordite (i.e. Cordite W). ➤ Cordite was produced by the incorporation of Nitrocellulose with Nitroglycerine in the presence of a solvent to assist gelatinisation. ➤ The resultant dough mixture was extruded into fine cords / elongated sticks or granules, which were gently heated to drive off the solvent. ➤ Nitrocellulose was prepared at ROF Wrexham by the nitration of cellulose (usually in the form of cotton or wood pulp) in the presence of nitric acid. The crude product was washed with hard water to neutralise the acid before being pulped and blended. Nitrocellulose would have been handled in a damp state in large volumes at the site. ➤ The nitric acid was also manufactured on-site and spent acid was recovered for re-use. ➤ Nitroglycerine was formed by nitrating glycerine in the presence of nitric acid and would have been used in large quantities at ROF Wrexham. ➤ ROF Wrexham was known to have produced 'Flashless' Cordite. This was produced by the inclusion of a large proportion of finely divided Nitroguanidine (Picrite). It would have been used in relatively large volumes in the form of a whitish powder. ➤ The production of Solventless Cordite at ROF Wrexham also included the use of Carbamate. The specific composition used was Nitroglycerine 29%, Nitrocellulose 65% and Carbamate 6%.

Section	Details
Contaminant Behaviour	➤ Cordite retains almost all of its original chemical nature and properties even over prolonged periods of burial and in a range of different soil types. When unconfined cordite will deflagrate rather than detonate. However, in confined spaces, such as drainage systems, it may produce effects associated with detonation and in all instances, confined or otherwise, it may add to the detonation force of other explosives. ➤ Nitrocellulose is an extremely stable product in environmental terms and is virtually insoluble and non-volatile. Over considerable periods of time it may degrade to very similar nitro-compounds which have similar form but which may be more likely to spontaneously detonate. ➤ Nitrocellulose is not considered to represent a significant toxicological risk to human health. ➤ Nitroglycerine is generally a colourless liquid or with a slight yellowish coloration. In its liquid state it is shock and friction sensitive. It can explosively decompose in contact with strong alkalis or acids. Crystalline or 'frozen' Nitroglycerine is highly shock and friction sensitive as crystals rubbing together can detonate. ➤ Nitroglycerine in drainage systems is known to become readily absorbed by the sediments and fragments rather than becoming mobile and then transported within the system. Nitroglycerine is almost insoluble in water, however, it is much more soluble in oils and other organic liquids. ➤ Nitroglycerine and Cordite may be toxicological at concentrations below those for which an explosive hazard is present. ➤ Picrite is a fine powder that is not shock or friction sensitive and is even difficult to combust. It is practically insoluble in cold water. ➤ Picrite is toxic to humans only when significantly elevated above the explosive risk concentration. ➤ Demolition wastes may be contaminated with a range of explosive and conventional compounds. Nitroglycerine and Picrite are particularly prone to contaminating porous surfaces such as building fabric. Nitroglycerine can even be absorbed through painted surfaces into the underlying brickwork. ➤ Cordite, Nitroglycerine, Nitrocellulose, Picrite and explosive devices represent a potential hazard to humans due to their explosive and highly flammable properties.
Other	➤ Anecdotal information indicates that filling of 1000lb shells has occurred at ROF Wrexham despite the fact that the factory was never designed for such purposes. It has been indicated that this operation was conducted in an unofficial capacity. Consequently, it is likely that any surplus or waste items would have been disposed of in a less desirable manner (e.g. in fireponds or waste water lagoons). ➤ Wartime measures meant that blast mounds were not always constructed for the production units. ➤ Cordite factories typically contained a range of ancillary services and infrastructure to support the manufacturing process. This would usually include dedicated on-site boiler houses, power houses and associated fuel storage or supply network, railway sidings, acid plant and acid recovery plant, electrical substations, steam generation and supply, mechanical and electrical workshops, laboratories and administration facilities. ➤ Steam was widely used for the heating and process work undertaking at the ROF Wrexham site and was delivered by a network of metal steam pipes. Pipes were usually insulated with asbestos based lagging. ➤ Asbestos may be present across the site as a result of poor remediation activities which may have occurred in the late 1940's when the ROF site was decommissioned. Asbestos may be present within demolition materials due to the extensive use of asbestos across explosives sites. ➤ Fireponds were constructed for use in the event of a fire. While not potentially contaminative BAE systems state that in their experience fireponds are often used for the unauthorised disposal of hazardous materials most notably the discarding of waste or surplus explosives and devices.

II. GroundSolve Ltd. Coed Aben Road, Wrexham Industrial Estate, Proposed Industrial Unit, Phase I & II Geoenvironmental Report

A site investigation was undertaken by GroundSolve Ltd. for the area approximately 610m to the north north east of the site in November 2014, with a subsequent factual and interpretative report being issued in December 2014.

These site investigation works comprised of the following:

Features	Details
Exploratory Holes	6 No. trial pits to depths of between 1.50m and 2.80m bgl.
Chemical Testing of Soils	5 No. solid chemical tests for a range of determinands.
Geotechnical testing of soils	2 No. Atterberg tests and 2 No. pH and SO ₄ tests.

Ground Conditions

A review of the ground conditions from the GroundSolve Ltd. site investigation indicates that the typical shallow ground conditions for the area immediately to the north west of the site are as follows:

- MADE GROUND comprising soft to firm / firm to stiff, reddish brown / brown, slightly silty CLAY with a little gravel, bricks, tile and metal to a depth of between 0.30m and at least 2.80m bgl, underlain by;
- Firm to stiff, very stiff in places, fissured, reddish brown to brown, orangish brown in places, slightly silty to very silty CLAY to a depth of between at least 1.70m and 2.00m bgl, where exploratory holes were terminated.

It should be noted that:

- Within a single trial pit, a firm to stiff, fissured, brown, very silty CLAY / loose to medium dense, clayey SILT was encountered from 0.65m to 1.70m bgl.

Groundwater

Groundwater was encountered within 2 No. of the trial pits at depths of between 1.50m and 2.40m bgl and were recorded as slight groundwater seepages at the base of the Made Ground.

Geotechnical Parameters

The Atterberg Testing undertaken on the natural Glacial Till recorded liquid limits of between 47 – 55%, plastic limits of between 21 – 24% and plasticity indices of between 25 – 31%, indicating clay of intermediate to high plasticity. Natural moisture contents were between 18 – 27%.

Obstructions

A concrete slab was encountered within one of the trial pits at a depth of 1.50m bgl and was not penetrated. A broken slab was also encountered within another trial pit at a depth of 1.90m bgl.

Environmental

The solid chemical tests undertaken are summarised in the table below:

Determinand	Concentrations (mg/kg except for sulphate and pH)	
	Range	Mean
Arsenic	8.55 – 12.2	10.2
Cadmium	<0.02	-
Chromium (total)	29.7 – 38.7	33
Chromium (hexavalent)	<0.60	-
Chromium (trivalent)	29.7 – 38.7	33
Lead	19.9 – 45	34.7
Copper	19.3 – 22.9	21.3
Mercury	<0.14	-
Nickel	30.8 – 40.3	34.8
Selenium	<1	-
Zinc	63.6 – 169	126
pH	8.29 – 8.77	8.56
Boron	14 – 18.8	15.4
Total Cyanide	<1	-
Sulphur	<10 – 271	63
Sulphate (Water Soluble)	<4 – 23	13
Sulphide	<15	-
Soil Organic Matter	0.664 – 1.69	1.27
Acenaphthene	<0.008 – 0.24	-
Acenaphthylene	<0.012 – 0.026	-
Anthracene	<0.016 – 0.93	-
Benzo(a)anthracene	<0.014 – 1.43	-
Benzo(a)pyrene	<0.015 – 1.29	-
Benzo(b)fluoranthene	<0.015 – 1.35	-
Benzo(k)fluoranthene	<0.014 – 0.639	-
Benzo(g,h,i)perylene	<0.024 – 0.68	-
Chrysene	<0.001 – 1.18	-
Dibenzo(a,h)anthracene	<0.023 – 0.179	-

Determinand	Concentrations (mg/kg except for sulphate and pH)	
	Range	Mean
Fluoranthene	<0.017 – 3.39	-
Fluorene	<0.001 – 0.23	-
Indeno(1,2,3-cd)pyrene	<0.018 – 0.592	-
Naphthalene	<0.009 – 0.018	-
Phenanthrene	<0.015 – 2.87	-
Pyrene	<0.015 – 2.58	-
Phenols	<0.01	-
Cresols	<0.01	-
MTBE	<0.005	-
Benzene	<0.01	-
Toluene	<0.002	-
Ethylbenzene	<3 – 5.8	-
M, p – xylene	<6	-
o – xylene	<3	-
Aliphatic EC 5-6	<0.01	-
Aliphatic EC >6-8	<0.01	-
Aliphatic EC >8-10	<0.01	-
Aliphatic EC >10-12	<0.01	-
Aliphatic EC >12-16	<0.1	-
Aliphatic EC >16-35	<0.1 – 31.2	-
Aliphatic EC >35-44	<0.1 – 17.4	-
Aromatic EC 5-7 (benzene)	<0.01	-
Aromatic EC >7-8 (toluene)	<0.01	-
Aromatic EC >8-10	<0.01 – 0.011	-
Aromatic EC >10-12	<0.01	-
Aromatic EC >12-16	<0.1	-
Aromatic EC >16-21	<0.1 – 8.45	-
Aromatic EC >21-35	<0.1 – 30.7	-
Aromatic EC >35-44	<0.1 – 20.4	-

Note 1 - Units are in mg/kg unless stated.

GroundSolve Ltd. state that no asbestos was encountered within any of the samples but that loose fibres were observed in a single sample but that there was insufficient material to undertake an identification and quantification test.

Based on the above results GroundSolve Ltd. state that at the time of writing no exceedances were recorded for the commercial / industrial land use. However, they also state that the site was probably backfilled with the blast banks surrounding the original war time structures. Consequently, any residual contamination from Cordite manufacture may be present at significant depth beneath the layer of backfill, at a depth of approximately 3m bgl.

III. ESI Preliminary Risk Assessment: Former Firestone Site, Wrexham Industrial Estate

ESI produced this report in December 2012 for an area approximately 370m to the east of the site, to provide clear and pragmatic advice regarding the nature and potential significance of any land quality hazards that may be present at the study site in question (Former Firestone Site).

In particular this outlined information pertaining to the former ROF Wrexham that had been largely obtained from a desk study report that had been undertaken for the wider area (BAE Systems, 2001. Desk Study for potential explosive contamination at Wrexham Industrial Estate, Report No: A120-00-R1-A-DRAFT). Unfortunately, this report was unavailable but ESI summarised the following pertinent information from this report:

Activity	Details
History	➤ Sometime during the late 1930's / early 1940's ROF Wrexham was constructed for the manufacture of cordite following the outbreak of World War II. ➤ Manufacture of cordite ceased in August 1945. ➤ At the end of the war the ROF land was sold for redevelopment as an industrial estate. ➤ It is unclear when the ROF buildings were demolished but at the Firestone site most were demolished by 1966 with the remainder being demolished at an unknown later date.
Contamination	➤ Potential contaminants identified included cordite, Nitroglycerine, Nitrocellulose, Nitroguanidine (picrate) explosive devices and asbestos. ➤ Records indicate that some areas of the ROF were potentially contaminated by explosive residues in drainage systems and on the floors of buildings. Remediation work was carried out in these areas but no further details, including when and where this occurred, were provided. ➤ ESI state that based on the small size, isolated nature and the orientation of the ROF structures they may have been used for the storage of raw / finished products rather than for manufacture. Consequently, contamination may be less likely than at other areas of the ROF. ➤ During subsequent site investigation works contamination was encountered across the former Firestone relating to historical activities associated with both the Firestone factory and the ROF (see previous SI Work in the table below).
Obstructions	➤ Records state that the former ROF buildings were demolished to ground level and then buried. ➤ Subsequent works at the former Firestone site encountered numerous obstructions pertaining to the former ROF. This included deep concrete slabs and underground pipework.

This report also reviewed several previous site investigations and a phase of remediation that had also been undertaken at the former Firestone site. While these reports were generally unavailable, ESI recorded the following pertinent information and this is included in the table on the following page:

Features	Details
JR Grimley (1992)	11 No. boreholes were drilled but other than their locations no details were made available.
Unknown but summarised in reports below (1993)	12 No. boreholes, 81 No. trial pits and 20 No. trial trenches were undertaken at the site in 1993. Overall 166 soil samples, 11 groundwater samples, 2 surface water samples and 3 samples from sumps were analysed. In total 33 soil samples and 7 water samples were found to be 'contaminated' with either hydrocarbons, various metals or alkaline pH (soils) and metals (lead and selenium), phenol, ammoniacal nitrogen and sulphate (in waters). The elevated hydrocarbon contamination was restricted to the east of the Firestone Building and it was concluded that this contamination was associated with occasional isolated and suspect material.
Travers Morgan (1994a)	35 No. trial pits were excavated as part of a site investigation undertaken in 1994. Over 100 soil samples and 9 groundwater samples were undertaken but the results were missing from the copy of the report that was available, which included only a summary of the findings. Visual evidence of contamination was noted in various locations and four of the samples were found to be 'heavily' contaminated due to sulphate, toluene extractable material (up to 28,400 mg/kg) and several metals (including lead up to 3,400 mg/kg). 12 No. soil samples were moderately contaminated due to elevated pH, sulphate, phenol, toluene extractable material and zinc).
Travers Morgan (1994b)	Details remediation works that were undertaken at the site that involved the excavation and removal of four identified areas of contamination for disposal. It was noted that these locations did not correlate with the majority of the locations where contamination had recently been recorded.
Symonds Travers Morgan (1995)	Details the site preparation works undertaken and confirms the four identified areas had been remediated and that the majority of structures from the former Firestone Factory and the former ROF Wrexham (including floor slabs; foundations; roadways; areas of hardstanding and pipework) to a depth of 3m had been removed; although they state that some obstructions had been left in-situ and that unrecorded obstructions may remain. One of the main areas of contamination was associated with one of the former MOD building locations.

As part of their preliminary risk assessment ESI assigned an overall low to medium risk for the former Firestone site but that former site investigation works should be undertaken to confirm this regime as there was an uncertainty regarding the remedial works that had been undertaken on-site.

IV. ESI Phase 2 Contaminated Land Investigation: Former Firestone Site, Wrexham Industrial Estate

A site investigation was undertaken by ESI Ltd. for an area approximately 370m to the east of the site (former Firestone Site) in November 2012, with a subsequent factual and interpretative report being issued in December 2012.

These site investigation works comprised of the following:

Features	Details
Exploratory Holes	38 No. trial pits to a depth of between 0.40m and 1.50m bgl.
Chemical Testing of Soils	33 No. solid chemical tests for a range of determinands that included analysis for explosive residue.
Chemical Testing of Groundwaters	4 No. groundwater chemical tests for a range of determinands.
On-site testing	Headspace measurements from soil samples were also undertaken using a Photo Ionisation Detector (PID).

Ground Conditions

A review of the ground conditions from the ESI site investigation indicate that the typical shallow ground conditions were as follows:

- MADE GROUND comprising firm to stiff, soft in places, reddish brown, sandy CLAY / loose, dark brown, clayey SAND / loose, black, sandy COBBLES of brick, all with fragments of demolition rubble (brick, concrete etc.) and small fragments of plaster, plastic, charcoal, metal, glass, ash and ceramics (noted as organic in places) to depth of between 0.20m and 1.40m bgl, underlain by;
- Firm to stiff, red to reddish brown, mottled blue CLAY / firm to stiff, grey green SILT / loose, blue and green SAND all to a depth of between 0.35m and 1.50m bgl, underlain by;
- Firm to stiff, red brown, sandy in places, CLAY with occasional gravel and cobbles (occasionally weathered on the upper surface) to a depth of between at least 0.40m and 1.50m bgl.

Groundwater

Groundwater was encountered within 4 No. exploratory holes at depths of between 0.60m and 1.00m bgl with slow to rapid flows being observed within some of the Made Ground strata that was encountered at the site.

ESI state that based on the above the no laterally continuous shallow groundwater body was observed at the site but that perched waters are present in isolated areas of the site. In particular these perched waters were associated with some very coarse granular backfill to a former structure or where buried structures (e.g. slabs) were present in the ground.

Obstructions

ESI state that the Welsh Development Agency undertook a series of site investigations at the site that including removing the foundations and below ground infrastructure that remained following the demolition of the former Firestone Factory and the ROF buildings. Despite, this several obstructions in the form of concrete slabs were encountered within some of the trial pits.

Environmental

Visual and olfactory evidence of contamination was noted during the site investigation works and this included blackened materials / staining in 5 No. adjacent trial pits, burnt shale in 2 No. trial pits and an oily sheen on the surface of some shallow groundwater within a single trial pit. No appreciable odours or VOC concentrations (PID measured) were noted.

The solid chemical tests undertaken are summarised in the table on the following page:

Determinand	Concentrations (mg/kg except for sulphate and pH)	
	Range	Mean
Metals		
Arsenic	2.2 – 22	9.7
Boron (water soluble)	<0.2 – 1.6	0.42
Barium	53 – 370	126
Beryllium	0.4 – 1.4	0.83
Cadmium	<0.2 – 16	0.75
Chromium (total)	11 – 45	28.1
Chromium VI	<4	-
Chromium III	11 – 45	28.1
Lead	14 – 300	63.6
Copper	5.9 – 68	21.3
Mercury	<0.3 – 1.3	0.33
Nickel	6.2 – 52	26.2
Selenium	<1 – 2.3	1.0
Vanadium	10 – 46	29.3
Zinc	39 – 2500	170.3
General Inorganics		
pH	6.6 – 8.5	7.9
Sulphate (Water Soluble)	14 – 520	104
Ammonium	<5	-
Organic Carbon Fraction	0.0006 – 0.032	0.009
Soil Organic Matter	0.1 – 5.5	1.5
Total Organic Content	0.1 – 3.2	0.9
Nitrate (Water Soluble)	<2 – 3.5	2.2
Polycyclic Aromatic Hydrocarbons		
Total PAH	<1.6 – 14	2.9
Acenaphthene	<0.1 – 0.2	0.1
Acenaphthylene	<0.2	-
Anthracene	<0.1 – 0.3	0.1
Benz(a)anthracene	<0.2 – 2.1	0.4
Benzo(a)pyrene	<0.1 – 2	0.3
Benzo(b)fluoranthene	<0.1 – 2.1	0.4
Benzo(k)fluoranthene	<0.2 – 1.4	0.3
Benzo(g,h,i)perylene	<0.05 – 1	0.2
Chrysene	<0.05 – 2.4	0.3
Dibenzo(a,h)anthracene	<0.2	-
Fluoranthene	<0.2 – 3	0.5
Fluorene	<0.2	-
Indeno(1,2,3-cd)pyrene	<0.2 – 1.1	0.2
Naphthalene	<0.05 – 0.74	0.17
Phenanthrene	<0.2 – 2.4	0.3
Pyrene	<0.2 – 2.8	0.5
Phenols		
Phenols	<2	-
Monoaromatics		
MTBE	<1	-
Benzene	<1	-
Toluene	<1	-
Ethylbenzene	<1	-
M, p – xylene	<1	-
o – xylene	<1	-
Petroleum Hydrocarbons		
Aliphatic EC 5-6	<0.1	-
Aliphatic EC >6-8	<0.1	-
Aliphatic EC >8-10	<0.1	-

Determinand	Concentrations (mg/kg except for sulphate and pH)	
	Range	Mean
Petroleum Hydrocarbons		
Aliphatic EC >10-12	<1	-
Aliphatic EC >12-16	<2 – 2.5	2.0
Aliphatic EC >16-21	<8 – 25	8.5
Aliphatic EC >21-35	<8 – 59	12.6
Total Aliphatic (E5 – E35)	<10 – 59	15.1
Aromatic EC 5-7	<0.1	-
Aromatic EC >7-8	<0.1	-
Aromatic EC >8-10	<0.1	-
Aromatic EC >10-12	<1	-
Aromatic EC >12-16	<2	-
Aromatic EC >16-21	<10 – 12	10.1
Aromatic EC >21-35	<10 – 30	12.4
Total Aromatic (EC5 – C35)	<10 – 38	12.8
Semi-Volatile Organic Compounds		
Dibenzofuran	<0.2 – 0.8	0.23
Explosive Compounds		
2,4,6-trinitrotoluene	<0.5	-
2,4-dinitrotoluene	<1.0	-
4,2-dinitrotoluene	<1.0	-
Hexanitrostilbene	<0.5	-
MHX	<1.0	-
PETN	<5	-
RDX	<1.0	-
Tetryl	<1.0	-
Picrite	<0.1	-
Picric Acid	<0.1	-
Ethylene Glycol Dinitrate	<0.1	-
Nitroglycerine	<0.1	-
Nitrocellulose	<5000	-

Note 1 - Units are in mg/kg unless stated.

ESI state concentrations of metals were modest and did not show any particular spatial distribution. The only volatile TPH fraction detected was from a sample within the former ROF area, as were several low concentrations of PAH. Non-volatile aliphatic and aromatic TPH fractions and low concentrations of PAH were associated with the former Firestone building. The only SVOC detected was associated with a sample of burnt shale. No asbestos containing materials were encountered or observed during the soil analyses. All explosive organic compounds were below their limits of detection.

At the time of writing ESI state that for human health the soil data was significantly below the GAC screening levels (assuming soil organic matter of 1%) for the proposed commercial / industrial land use

The groundwater chemical tests undertaken are summarised in the table below:

Determinand	Concentrations (mg/l except for pH)
	Range
Metals	
Arsenic	0.0019 – 0.015
Boron	0.064 – 0.18
Barium	0.062 – 0.17
Beryllium	<0.0002
Cadmium	<0.001
Chromium	<0.004 – 0.008
Lead	0.0013 – 0.0043
Copper	0.0023 – 0.0045
Mercury	<0.0005
Nickel	0.0009 – 0.0029
Selenium	<0.004
Vanadium	<0.0017 – 0.0059
Zinc	<0.0004 – 0.0017
Inorganics	
pH	7.2 – 7.4
Sulphate as SO ₄	44.2 – 220
Sulphide	<0.005
Chloride	0.0018 – 0.05
Ammoniacal Nitrogen as N	0.00012 – 0.00067
Nitrate as N	<0.01
Nitrite as N	<0.01 – 0.12
Polycyclic Aromatic Hydrocarbons	
Total PAH	<0.00001
Acenaphthene	<0.00001
Acenaphthylene	<0.00001
Anthracene	<0.00001
Benz(a)anthracene	<0.00001
Benzo(a)pyrene	<0.00001
Benzo(b)fluoranthene	<0.00001
Benzo(k)fluoranthene	<0.00001
Benzo(g,h,i)perylene	<0.00001
Chrysene	<0.00001
Dibenzo(a,h)anthracene	<0.00001
Fluoranthene	<0.00001
Fluorene	<0.00001
Indeno(1,2,3-cd)pyrene	<0.00001
Naphthalene	<0.00001
Phenanthrene	<0.00001
Pyrene	<0.00001
Monoaromatics	
MTBE	<0.001
Benzene	<0.001
Toluene	<0.001
Ethylbenzene	<0.001
M, p – xylene	<0.001
o – xylene	<0.001
Petroleum Hydrocarbons	
Aliphatic EC 5-6	<0.01
Aliphatic EC >6-8	<0.01
Aliphatic EC >8-10	<0.01
Aliphatic EC >10-12	<0.01

Determinand	Concentrations (mg/l except for pH)
	Range
Petroleum Hydrocarbons	
Aliphatic EC >12-16	<0.01
Aliphatic EC >16-21	<0.01
Aliphatic EC >21-35	<0.01
Total Aliphatic (E5 – E35)	<0.01
Aromatic EC 5-7	<0.01
Aromatic EC >7-8	<0.01
Aromatic EC >8-10	<0.01
Aromatic EC >10-12	<0.01
Aromatic EC >12-16	<0.01
Aromatic EC >16-21	<0.01
Aromatic EC >21-35	<0.01
Total Aromatic (EC5 – C35)	<0.01

ESI state that there was an absence of BTEX, TPH, SVOCs (including PAH) or VOCs within the shallow groundwater samples tested. Metal concentrations were generally low; however modest ammoniacal nitrogen, nitrite and sulphate concentrations were observed.

ESI state that the assessment undertaken indicates that the shallow groundwaters are being impacted by arsenic, ammoniacal nitrogen and nitrite. However, they believe that the shallow groundwater is very isolated and that the absence of a continuous shallow groundwater body suggests that continuity with nearby receptors is unlikely. Furthermore, only very limited attenuation and dilution would be required to reduce the observed concentrations below their target levels. Regarding the deeper bedrock aquifers ESI state that they are covered by a significant thickness (approximately 40m) of clayey superficial deposits. Consequently, the risk to control waters was determined to be low.

Ground Gas Monitoring

ESI state that using the approach outlined by Card and Wilson (2011) for low gas risk sites the site appears to have a low risk of gas generation with most of the locations equating to Characteristic Situation 1 (CS1). However, a number of locations were indicative of CS2 and some localised areas may equate to CS3. They state that for most of the site, standard construction methods can be used to provide the necessary gas protection for the new buildings. For the areas indicative of CS3 they

recommended selected treatment and removal of any degradable content prior to construction.

Due to the limited gas generation potential and the lack of any lateral migration pathways due to the clayey nature of the soils, it was unlikely that a risk was posed to buildings on adjacent sites.

It should be noted that ESI do not mention the risk posed from vapours during their preliminary ground gas risk assessment.

6.15 Unexploded Ordnance (UXO)

A review of the Zetica UXB Risk Maps shows that the site lies within a low-density bombing area. However, the site lies within an area designated as a former strategic target (ROF Wrexham) and a military site was located approximately 1.25km to the south east of the site.

Anecdotal evidence obtained suggests that potential bomb strikes were recorded within the wider area but it could not be confirmed if any bomb strikes had been recorded on-site; although this cannot be discounted.

Numerous defensive structures are recorded for an area approximately 1km to the south east of the site. The nearest is located 1km to the east of the site and pertains to a Pillbox and an Anti-Tank Block. Other defensive structures include other Pillboxes and Defended Buildings.

There are no ruins recorded on historical maps from around the time of World War 2.

Previous reporting (see Section 6.14) states that the site may be contaminated with explosive devices associated with the sites former use as ROF Wrexham. Anecdotal information also indicates that filling of 1000lb shells has also occurred at ROF Wrexham despite the fact that the factory was never designed for such purposes.

6.16 Subterranean Features / Underground Services

Due to the wider areas historic use as former ROF Wrexham many of the structures were likely designed to a blast proof specification and may have been partially located below ground. Anecdotal evidence also indicates that there was a series of underground tunnels connecting the various buildings.

Previous reporting (see Section 6.14) states that following the demolition of ROF Wrexham most of the buildings were demolished to ground level and that subterranean features were either left in-situ or backfilled. Consequently, numerous subterranean features may be present beneath the site and this could include concrete slabs / walls / foundations, potential basements, drains and other services, underground tunnels, roadways and railway tracks.

Those potential subterranean features noted on-site are included within the site features plan contained within Appendix 9.

Details pertaining to existing underground services can be found within the Integra Consulting Utilities Infrastructure Report (ref: 3036 – 12).

7.0 CONCLUSIONS

7.1 General History

As a result of undertaking a walk over survey of the site and reviewing the available desk study information, it has been concluded that since prior to the 1872 the site and its surrounds were undeveloped open / rural land. As a number of suspected farms were recorded in the surrounding area there is also a possibility that the site may have been in use as agricultural land.

Sometime between the late 1930's and late 1940's, part of ROF Wrexham had been constructed across the site and the wider area for the manufacture of Cordite. Planning of ROF Wrexham is recorded to have commenced in May 1939 and initially the factory was to be a duplicate of the three cordite production units located at ROF Bishopton. However, only two units were ever constructed at ROF Wrexham due to a lack of labour.

Following numerous disputes regarding the sites eventual location, instruction to proceed with the construction of ROF Wrexham was given at the end of August 1939. Initially construction was expected to take 18 months from the date of instruction, but as some of the workforce had to be transferred to start work within the newly constructed first unit, the second unit took much longer to build than originally envisaged.

By December 1940 there were 500 people producing cordite at ROF Wrexham and production had reached approximately 480 tons a week. The two units had initially been planned to produce only 130 tons a week, so it is likely that productivity was of the utmost importance and perhaps standards of housekeeping less so. By this time the prospect of the third unit had been abandoned and the plant was transferred to Irvine, Scotland.

ROF Wrexham became fully operational in February 1941 just over a year after the start of construction. By January 1942 the total number of workers employed at ROF

Wrexham was recorded as 6095. Later that year increased production was gained by installing an acid plant from Huddersfield. During this time the maximum recorded production at ROF Wrexham was 520 tons per week and this was maintained for a short while until production halved shortly afterwards.

Operation of ROF Wrexham ceased on 11th August 1945. Either just before or following the closure of the site the Royal Ordnance Propellant Division are recorded to have conducted an inventory of capital assets for the ROF Wrexham site.

Shortly after closure, ROF Wrexham was sold for redevelopment as an Industrial Estate, with the current Wrexham Industrial Estate being established in the wider area sometime during 1946. Records also indicate that remediation works were carried out at this time but unfortunately the documents pertaining to these works could not be obtained.

Sometime during the late 1960s / late 1970s the structures pertaining to ROF Wrexham are no longer recorded at the site and most of the structures within the surrounding area are also no longer recorded. It is unknown if the former ROF structures were fully demolished, but previous site investigation works within the surrounding area indicate that some of the buildings were only demolished to ground level and then backfilled. By this time much of the surrounding land has also been redeveloped for industrial / commercial use.

It is not until the late 1970's to early 1980's that the remaining on-site and surrounding off-site features pertaining to former ROF Wrexham (e.g. blast bunds, mounds and cuttings) are no longer recorded. During this time further commercial / industrial development is also recorded to have occurred within the surrounding area.

By the early 1990's industrial development has occurred within the immediately surrounding area. Industrial development of the surrounding area continues until at least 2014 and the site is recorded as predominantly undeveloped to the present day.

7.2 Anticipated Ground Conditions

Based on the desk study information and the previous site investigation works reviewed; the ground conditions beneath the site are anticipated to be highly variable. This is due to the former historic site uses and a complex series of natural depositional processes that have resulted in Glacial Till overlying a well-developed series of Laminated Clay Till (which may also contain Glacial Silt), possibly interdigitated with Glacial Sands, which are in turn underlain by Lower Glacial Till deposits. There is also the possibility for River Terrace Deposits to be present at the site. Solid geology is recorded as the Salop Formation.

The thickest deposits of these Laminated Clay Tills are recorded around the Wrexham Industrial estate and are believed to have been deposited during the last ice age within a large glacial lake and possibly other transient lakes that were present in the area. These lakes became ice dammed by the retreating Irish Sea Glacier, which blocked natural drainage to the Irish Sea. Consequently, deposition of glacial soils began to occur within the lakes (Hains, et al. 1991).

At roughly the same time a complex outwash fan of Glacial Sands and Gravels were being deposited on the western margin of this proglacial lake and form the extensive sands and gravels of the Wrexham Delta Terrace, that occupy the higher ground around Wrexham (Hains, et al. 1991). These deposits may also be interdigitated with the Laminated Clay Tills noted above.

Finally, a minor ice sheet re-advance is believed to be responsible for the deposition of the Glacial Till that now covers the Laminated Till and Glacial Sand and Gravels and this is why the BGS Geological Maps record the natural superficial deposits as Glacial Till. This re-advance is also likely partly responsible for the interdigitation of Glacial Till and Glacial Sands and Gravels (Hains, et al. 1991).

Consequently, the natural superficial deposits beneath the site could be very variable and have significantly different engineering behaviour to that of typical Glacial Till (e.g. Boulder Clay).

7.2.1 Typical ground Conditions

Based on the above, the following typical underlying ground conditions are anticipated for the site:

- MADE GROUND comprising soft, brown CLAY with traces of tree roots and streaks of black topsoil to an approximate depth of between 0.50m and 0.75m bgl (but may be more significant and with obstructions at the location of former buildings and infilled ponds), underlain by;
- Firm to stiff, locally soft to firm, brown CLAY with streaks of grey silt and seams of sand to an approximate depth of between 3.00m and 5.00m bgl, underlain by;
- Very soft to soft, saturated, brown, sandy SILT and / or very loose saturated brown SAND with traces of coal to an approximate depth of at least 11m bgl (running conditions noted), underlain by;
- Firm to stiff, soft in places, laminated, brown, sandy, silty CLAY with beds and lenses of brown, silty, fine to medium sand and beds and lenses of soft, brown silt to an approximate depth of 25m bgl, underlain by;
- Brown, silty, fine SAND and GRAVEL to an approximate depth of 30m bgl, underlain by;
- Local borehole information is limited from this point onwards but a complex sequence of clays, laminated clays and interdigitated glacial sands, underlain by stiff to very stiff boulder clay with occasional cobble and boulders is envisaged to an approximate depth of 40m bgl, underlain by;
- Weak (completely weathered to a soft to hard, silty clay within the top 1 – 3m), purple, red, grey and brown, thinly bedded, MUDSTONE containing siltstone and shale interbedded with thin beds of moderately strong, reddish brown and grey, thinly bedded, fine grained, micaceous sandstone.

Exceptions to the above may occur within the southernmost section of the site due to the presence of the nearby River Terraces Deposits. However, due to the sites elevated position from those boreholes in which River Terrace Deposits were encountered, the likelihood of River Terrace Deposits being located on-site is considered to be low.

It should be noted that due to the variability exhibited by the natural superficial deposits in the area the above superficial sequence could vary significantly.

7.2.2 Obstructions

Due to the historical development that is recorded to have occurred across the site, there is a possibility that significant obstructions may be present in the ground; particularly at the location of former ROF structures, infrastructure and areas of potential backfilling.

This has been the case for former site investigation works undertaken within the surrounding area and this indicates that following the demolition of ROF Wrexham most of the buildings were demolished to ground level only and that subterranean features were either left in-situ or backfilled.

Consequently, numerous subterranean features may be present beneath the site and this could include concrete slabs / walls / foundations, potential basements, drains and other services, underground tunnels, roadways and railway tracks.

7.2.3 Groundwater

Based on nearby site investigation works perched waters are likely to be present within any Landscaped / Made Ground deposits of variable permeability that are present at the site and are underlain by low permeability natural Devensian Till; in particular this could pertain to infilled ponds and former structures that were present on-site.

Several of the BGS Boreholes reviewed also encountered numerous perched groundwater tables within the natural superficial deposits; predominantly whenever granular layers of sufficient thickness and extent were encountered. These ground water tables ranged between 1.65m and 1.70m bgl, between 3.00m and 3.50m, between 4.80m and 6.50m bgl, between 9.20m and 10.20m, between 17.60m and 21.64m and between 24.69m and 26.82m.

With the exception of the water strike at 4.80m bgl and those water strikes above this depth; all the boreholes recorded artesian conditions with waters rising close to the ground surface. This coincides with springs noted on historical maps and the artesian conditions recorded within the sands and gravels beneath the Wrexham Industrial Estate (Hains, et al. 1991).

Groundwater flow direction within the natural superficial deposits is likely complex and will likely be dictated by the interconnectivity of the sands and gravels within the low permeability Glacial Till. However, to a large extent regional groundwater flow within the natural superficial deposits will be from areas of increased elevation to areas of lower elevation (e.g. towards the River Clywedog to the south east).

Deeper groundwater within the underlying solid geology was not encountered within any of the boreholes reviewed and is anticipated to be located at a significant depth beneath the site (<40m) and flowing downdip towards the east.

Furthermore, due to the faulting that is recorded approximately 400m to the north west of the site the less permeable Salop Formation is juxtaposed against the adjacent permeable Kinnerton Sandstone Formation. Consequently, along with the fault the Salop Formation is likely acting as a barrier to local deep groundwater flow within the Kinnerton Sandstone Formation; although thin sandstone bands within the Salop Formation may be water bearing.

7.3 Contaminated Land Legislative Framework

Environmental risks are assessed in accordance with Contaminated Land (England) (Amendment) Regulations (2012), Part IIA of the Environmental Protection Act 1990, and Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance, DEFRA (2012). Part IIA provides a statutory definition of contaminated land. To fall within this definition it is necessary that, as a result of the condition of the land, substances may be present on or under the land such that:

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

Risk from contamination is assessed by consideration of possible linkages between contaminant sources and potential receptors which could be harmed or polluted and the potential pathways between them – known as the Contaminant Linkage. For a risk of pollution or environmental harm to occur as a result of ground contamination, all of the following elements must be present:

- A source – a substance that is capable of causing pollution or harm;
- A receptor – something which could be adversely affected by the contaminant; and
- A pathway – a route by which the contaminant can reach the receptor.

If one of these elements is absent there can be no significant risk. If all are present then the magnitude of the risk is a function of the magnitude and mobility of the source, the sensitivity of the receptor and the nature of the migration pathway.

The Environment Agency Contaminated Land Report CLR 11 Model Procedures for the Management of Land Contamination provides the technical framework for structured decision making about land contaminations. CLR 11 advocates a phased approach to risk assessment comprising:

- Preliminary Risk Assessment (PRA) – desk study and qualitative assessment;

- Generic Quantitative Risk Assessment (GQRA) – assessment of contaminant concentrations against generic assessment criteria; and
- Detailed Quantitative Risk Assessment (DQRA) – detailed site-specific risk assessment and development of site-specific assessment criteria.

Each of these phases follows the same basic steps but adds site specific details and further certainty into the assessment as the stages progress. The basic steps are:

- Hazard Identification and hazard assessment – development or refinement of the source-pathway-receptor conceptual model, and identification of potential pollutant linkages;
- Risk Estimation – qualitative risk estimation predicting magnitude and probability of potential consequences that may arise as a result of a hazard; and;
- Risk Evaluation – deciding whether a risk is unacceptable.

The key to the classification is that the designation of risk is based upon the consideration of both:

- (a) the magnitude of the potential consequence (i.e. severity; considers both the potential severity of the hazard and the sensitivity of the receptor); and;
- (b) the magnitude of probability (i.e. likelihood; considers both the presence of the hazard and receptor and the integrity of the pathway).

Generic Quantitative Risk Assessment (GQRA) will utilise generic assessment criteria (GAC) for the purposes of screening allowable concentrations in comparison to the measured site concentrations. The GAC are defined based on the critical receptors identified at the site. Receptors are considered in relation to:

- Human health receptors (e.g. site users) via measured solid concentrations; and;
- The water environment (e.g. groundwater and surface water) via measured leachate / water concentrations.

Additional receptors may be relevant dependant on the site (e.g. flora/fauna, water supply pipes, buried concrete).

The GAC adopted for assessment of soils in relation to Human Health are based on published Soil Guideline Values (SGV) in 2009 for those compounds for which published criteria are available for varying scenarios (residential, commercial, allotment). In the absence of SGVs the following GAC defining documents are adopted – LQM/CIEH S4ULs (2015), CL:AIRE Soil GAC for Human Health Assessment (2010) and Category 4 Screening Levels (C4SL's) (2014).

GACs for waters must be selected to assess potential risks to the identified environmental receptors. There are numerous UK and European guidelines for waters based on the site situation and different receptors. GACs utilised include – The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2009 (Part 7: Groundwater Threshold Values), UK Drinking Water Standards (2000), Environmental Quality Standards, World Health Organisation concentrations, Environment Agency guidance concentrations and United States Environmental Protection Agency – Region 9 GACs.

7.4 Sources of Contamination and Probable Contaminants

Based on the desk study information reviewed the following on and off-site potentially contaminative sources have been identified.

7.4.1 Potentially Contaminative On-Site Sources

The most significant potentially contaminative source that was located on-site pertains to former ROF Wrexham, which was principally constructed for the manufacture of Cordite. This involved the use of explosive and toxic contaminants such as Nitroglycerine (NG), Nitrocellulose (NC) and possibly Nitroguanidine (Picrite); as well as other conventional contaminants.

While the relevant DOE Industry Profile indicates that numerous potentially contaminative activities could have occurred and that unrecorded disposal may have been occurring at ROF Wrexham (see table below); consultations with BAE Systems Ltd. indicates that the site was actually located within a section of ROF Wrexham that was towards the end of the production cycle and where potentially less contaminative activities are likely to have occurred.

Those potential activities that may have occurred at ROF Wrexham; in their entirety, along with those other potentially contaminative on-site sources, are included within the tables on the following page:

Potentially Contaminative Source	Associated Determinands*	Associated Activities*	Potential Severity / Significance
Historic On-Site ROF Wrexham	<i>Explosives (cordite, nitroglycerine, nitroguanidine); Hydraulic oils; Fuel oils, Total Petroleum Hydrocarbons; PCBs; Asbestos; Chlorinated Organic Solvents; Metals (e.g. chromium, nickel and zinc), carbonates (e.g. calcium) and Carbamide</i>	➤ Despite the range of potentially contaminative activities that may have occurred at ROF Wrexham (see 7.4.2) records indicate that the site is located within a section of ROF Wrexham that was towards the end of the production cycle and where potentially less contaminative activities are likely to have occurred. ➤ Historical building plans indicate that the blending houses were located on-site. ➤ The blending houses were where different batches of cordite were mixed together to maintain a consistent product. ➤ Numerous underground pipes would have led from each building to transfer process effluent etc. to various parts of the site. This is confirmed on the historical building plan extract provided that indicates that process effluent, fire and regular domestic pipes were present beneath the site. ➤ At the blending houses contamination can arise from reject cordite being discarded during packaging and / or fragments of cordite being swept into drainage systems or being swept outside of buildings directly to the soil. ➤ Due to the extensive use of asbestos across explosives sites (e.g. lagging for steam pipes) and the poor remediation activities which may have occurred in the 1940's, when the ROF site was decommissioned, asbestos may be present within demolition materials and in landscaped soils (possibly at lower concentrations).	Medium
Existing and Abandoned On-Site Drainage / Infrastructure	<i>ACM's and contamination associated with the sites former use as ROF Wrexham and possibly other surrounding site uses</i>	➤ Previous reporting indicates that if any residual contamination is remaining from the ROF Wrexham site then it may be located within historical drainage. ➤ Nitroglycerine in drainage systems is known to become readily absorbed by the sediments and fragments rather than becoming mobile and then transported within the system. Nitroglycerine is almost insoluble in water, however, it is much more soluble in oils and other organic liquids. ➤ When unconfined cordite will deflagrate rather than detonate. However, in confined spaces, such as drainage systems, it may produce effects associated with detonation and in all instances, confined or otherwise, it may add to the detonation force of other explosives. ➤ Sediment contaminated with more conventional contaminants may also be present within existing and abandoned drainage that is present beneath the site. ➤ Leaks may be occurring from pipework that may contain contaminated waters from the immediately surrounding areas. ➤ Due to the age of any on-site drainage / infrastructure asbestos containing materials may be present within pipework.	Medium
Landscaped Ground and Infilled Excavations	<i>Unknown – suspected to comprise those materials and determinands associated with the historic ROF Wrexham and possibly other surrounding potentially contaminative sources (see Section 7.4.2)</i>	➤ Following the demolition of ROF Wrexham many of the blast bunds, demolition rubble and other excavated soils from the immediately surrounding area are likely to have been used in the landscaping of Wrexham Industrial Estate. Consequently, those contaminants associated with nearby activities that are recorded to have occurred at ROF Wrexham may be present but possibly at low concentrations due to soil remixing following landscaping of the site. ➤ It is unlikely that contaminated soils or wastes from other sections of ROF Wrexham would have been deposited at the site. However, unauthorised disposal of potential contaminants may have occurred from other areas of ROF Wrexham in former excavations and then backfilled. If located at a sufficient depth they may have not been disturbed by later landscaping. ➤ Asbestos fibres from demolition of former ROF structures may be present within the soils. ➤ If made ground has been imported to the site following the sites use as ROF Wrexham then this could constitute another potentially contaminative source with determinands associated with other potentially contaminative sources.	Medium

Potentially Contaminative Source	Associated Determinands*	Associated Activities*	Potential Severity / Significance
Historic Infilled Ponds	<i>Unknown – suspected to comprise those materials and determinands associated with the historic ROF Wrexham and possibly other surrounding potentially contaminative sources (see Section 7.4.2)</i>	➤ The historic pond that was located on-site is suspected to have been infilled during the operation of ROF Wrexham. Consequently, those contaminants associated with ROF Wrexham could be present due to the unauthorised disposal of hazardous materials; most notably the discarding of waste or surplus explosives and explosive devices. ➤ If made ground has been imported to the site following the sites use as ROF Wrexham then this could constitute another potentially contaminative source with determinands associated with other potentially contaminative sources.	Medium
Current Site Use	<i>Unknown</i>	➤ Other than the recent clearance of vegetation the site does not appear to have current site use. ➤ Potential minor or localised contamination may have occurred that relates to unauthorised use of the site (e.g. minor fuel spills, disposal of wastes etc.).	Low

* DOE profiles give information on the contamination which may be associated with specific industries. The list is not exhaustive; neither does it imply that all these chemicals might be present at individual sites

It should be noted that potentially contaminative unrecorded historic activities (e.g. burning grounds associated with ROF Wrexham) may have occurred and, in this event, further contaminative sources may be present.

The site features plan contained within Appendix 9 provides the approximate locations for the majority of the above noted on-site potentially contaminative sources.

7.4.2 Potentially Contaminative Off-Site Sources

Contamination from off-site sources has to migrate to the site, generally in windblown or soil-derived dust, entrained in surface water runoff, in migrating groundwater and as migrating ground / landfill gas and vapours. Disposal of contaminated materials and other wastes from off-site sources may also have occurred on-site; particularly if unauthorised disposal of potentially hazardous materials and during the landscaping that is recorded to have occurred.

Of those potentially contaminative off-site sources identified in previous sections, the following sources; based on their proximity to the site, their significance and the integrity of the pathways noted above, are considered the most likely to have affected the site:

Potentially Contaminative Off-Site Source	Distance / Direction from Site	Potential Associated Determinands*	Associated Activities*	Potential Severity / Significance
Wider Historic ROF Wrexham	0 – 500m Various	<i>Acids (nitric, sulphuric and possibly acetic acid); Organic solvents (e.g. acetone, ether, ethanol, diethyl ether, ethyl carbonate, triacetin and possibly cyclohexanone); Organic compounds (e.g. diphenylamine, dinitrotoluene, diphenylamine, ethyl centralite, glycerine and possibly hexamine, toluene, mononitrotoluene, polymers, glycerine, phenol, anilines, aldehydes, organic esters, acetic anhydride, guanidine nitrate and dicyanodiamide); Inorganic Compounds (e.g. potassium sulphate, nitrate ions, sulphate ions and possibly ammonium nitrate, sodium nitrate, potassium nitrate, sodium sulphite, sodium perchlorate and potassium perchlorate); Explosives (nitrocellulose, nitroglycerine, nitroguanidine and ammonium picrate but possibly 2,4,6-trinitrotoluene (TNT), Cyclotrimethylene trinitramine (RDX), Cyclotetramethylene tetranitramine (HMX), Pentaerythritol tetranitrate (PETN) and 2,4,6-trinitrophenol nitroguanidine (picric acid)); Hydraulic oils; Fuel oils, Total Petroleum Hydrocarbons; PCBs; Asbestos; Chlorinated Organic Solvents; Metals (e.g. chromium, nickel and zinc), carbonates (e.g. calcium) and Carbamite.</i>	➤ While those immediately surrounding site uses and activities associated with ROF Wrexham (e.g. drying houses and blending milling) are considered to have a low to moderate contaminative potential, those ROF site uses and activities located further afield are likely to have an increased contaminative potential. Consequently, a more general description of the activities associated with ROF Wrexham are included below. ➤ The two production facilities at ROF Wrexham were built specifically for the production of solventless Cordite. The Cordite is recorded to have been produced by the incorporation of Nitrocellulose (NC) with Nitroglycerine (NG) in the presence of a solvent to assist gelatinisation. The resultant dough mixture was then extruded into fine cords / elongated sticks or granules, which were gently heated to drive off the solvent. ➤ NC was prepared at ROF Wrexham by the nitration of cellulose (usually in the form of cotton or wood pulp) in the presence of nitric acid. The crude product was washed with hard water to neutralise the acid before being pulped and blended. NC is recorded to have been handled in a damp state in large volumes at the ROF Wrexham site. ➤ The nitric acid was manufactured at ROF Wrexham as it had its own acid plant. Spent acid was recovered for re-use. ➤ NG was formed by nitrating glycerine in the presence of nitric acid and was used in large quantities at ROF Wrexham. ➤ ROF Wrexham was also known to have produced 'Flashless' Cordite. This was produced by the inclusion of a large proportion of finely divided Nitroguanidine (Picrite). It is recorded to have been used in relatively large volumes in the form of a whitish powder. ➤ The production of Solventless Cordite at ROF Wrexham also included the use of Carbamite. The specific composition used was NG 29%, NC 65% and Carbamite 6%. ➤ Anecdotal evidence indicates that military secondary explosives (e.g. 1000lb shells) were being filled on-site. Consequently, those activities and contaminants associated with military secondary explosives may have occurred, which involved the nitration of solid or liquid organic compounds in batch or continuous processes. ➤ Historically, the majority of raw materials would have been delivered by rail as ROF Wrexham had its own mineral railway. ➤ Bulk liquids would have been transferred from tankers to storage vessels using a permanent overhead or underground pipe network. These liquids would then be transferred using pump systems to process or storage areas. ➤ Liquid effluent was not produced in significant quantities in the manufacture of propellants; although the manufacture of nitrocellulose and nitroguanidine can give rise to acid effluents of varying strengths and ROF Wrexham is recorded to have had its own acid plant. ➤ The anecdotal manufacture of explosives for shells may have generated considerable volumes of liquid effluent consisting mainly of acids, organic liquids and water, containing small amounts of dissolved or suspended explosive. High levels of nitrate and sulphate compounds would have been common. ➤ On-site disposal of materials was significant during the war years. Many explosives sites received Crown immunity from prosecution so this encouraged the quick disposal of wastes. For example: ✓ Waste effluent (e.g. from the manufacture of NC, NG and nitroguanidine) may have been allowed to discharge directly into surface waters. ✓ Wastewaters (e.g. from the cleaning down of process buildings and plant which contain explosives) may have been discharged to untreated soakaways, which could have led to isolated pockets of explosive contamination in soil at these locations.	Medium / High

Potentially Contaminative Off-Site Source	Distance / Direction from Site	Potential Associated Determinands*	Associated Activities*	Potential Severity / Significance
Wider Historic ROF Wrexham	0 – 500m Various	<i>As above.</i>	✓ Disposal of solid wastes (including propellants) by on-site burning. After burning the resultant ash was dowsed with water, which could then soak to the ground. This was often one of the major sources of contamination within the ground. ✓ Production wastes, contaminated building rubble (potentially asbestos containing) and wastes from ancillary processes, including boiler ash, may have been disposed of in unlined waste tipping areas or for infilling excavations. ➤ Cordite factories typically contained a range of ancillary services and infrastructure to support the manufacturing process. This would usually include dedicated on-site boiler houses, power houses and associated fuel storage or supply networks, railway sidings, acid plant and acid recovery plant, electrical substations, steam generation and supply, mechanical and electrical workshops, laboratories and administration facilities. Consequently, PCBs, fuel oil, petroleum, hydrocarbons and other hydraulic oils, which were used in propellant extrusion, may also be present. ➤ Steam was widely used for the heating and process work on the ROF Wrexham site and this was delivered by a network of metal steam pipes. Pipes were usually insulated with asbestos based lagging. ➤ General areas of soil contamination are likely to be associated with process buildings, storage and transfer areas for product or raw materials, near waste storage areas, wastewater drainage systems, overhead or underground pipework, wastewater treatment plants, burning grounds, proofing ranges, waste tipping areas and surface water soakaways. ➤ Contamination may arise from accidents, spillages or leaks from drains, sumps and tanks. Failure of drainage, tanks and sumps was common due to the corrosive nature of some of the acid-containing effluents.	Medium / High
Historic Landfill	978m NE	<i>Unknown – but is recorded to have received industrial waste and liquid sludge and operated between 1953 and 1983.</i>	➤ High contaminative potential as highly elevated concentrations for a range of contaminants are likely to be present. ➤ However, the size of the landfills are not significant so relatively small volumes of waste are envisaged.	Medium
Historic Infilled Ponds	20 – 250m Various	<i>Unknown – suspected to comprise those materials and determinands associated with the historic ROF Wrexham</i>	➤ Most of the historic ponds within the area are recorded to have been infilled during the operation of or shortly after the closure of ROF Wrexham. Consequently, those contaminants associated with surrounding ROF Wrexham could be present.	Medium
Historic Mineral Railway	50m W	<i>Fuel oils; Lubricating oils; Paraffin; PCB's, PAH's; Solvents; Ethylene glycol; Creosote; Herbicides; Ferrous residues; Metal fines; Asbestos; Ash; Sulphate but could also contain those raw materials from ROF Wrexham due to spillages and leaks etc.</i>	➤ Low to moderate contaminative potential due to the mineral railway and the potential for explosives contamination during the loading of the finished cordite product onto trains. ➤ Explosive contaminants and more conventional contaminants may be present within railway ballast; particularly in locations where locomotives are stationary (e.g. at stations or loadings areas) or bends in the tracks where trains would have to slow down.	Low to moderate

Potentially Contaminative Off-Site Source	Distance / Direction from Site	Potential Associated Determinands*	Associated Activities*	Potential Severity / Significance
RF Bellis Haulage Ltd	45m W	<i>Metals and their compounds including lead, chromium, zinc, copper, vanadium; Acids/alkalis; Asbestos; Organic compounds including non-halogenated solvents, halogenated solvents; Phenols/polycyclic aromatic hydrocarbons (PAHs).</i>	➤ Moderate contaminative potential but information on the RF Bellis Website indicates that the main operation of the site is as a warehouse or distribution depot for the storage of various goods. The facility is also relatively modern and will likely be subject to modern working practices. Consequently, it is unlikely that most of those activities noted within the relevant DOE Industry Profile will be applicable. Those believed to be the most applicable are outlined below: ✓ Accidental spillages of goods may have occurred during storage and loading / off-loading. The type of goods stored at the warehouse are unknown but are likely to be various. ✓ Small-scale vehicle maintenance may have occurred which may have resulted in small spillages of fuel lubricating oils, brake fluids and anti-freeze liquids.	Low
Wilsons Accident and Repair Centre	30m NW	<i>Metals and their compounds (lead, chromium, zinc, copper, vanadium); Acids / alkalis; Asbestos; Organic compounds (non-halogenated solvents, halogenated solvents, PAH's, fuels / hydrocarbons, ethylene glycol, polymerised glycols and ethers, detergents)</i>	➤ Moderate contaminative potential but due to modern working practises the contaminative potential is significantly reduced. The facility is also relatively modern and will likely be subject to modern working practices. Consequently, it is unlikely that most of those activities noted within the relevant DOE Industry Profile will be applicable. Those believed to be the most applicable are outlined below: ✓ Contamination may occur from the storage, handling, leakage and disposal of raw materials and waste products. ✓ If present leaks may occur from underground storage tanks and pipework; redundant tanks may also present problems. ✓ New and used lubricating oils are usually stored on-site in metal containers and storage tanks. Only a few garages are likely to have stored over 1000 gallons of waste oil. Even when holding tanks have been used spillages or leaks due to inadequate bunding can still occur. ✓ Waste brake fluid is generated during repair work on brake systems. A variety of solvents are used in cleaners, degreasers, thinners, fillers, adhesives, paints and strippers. Unauthorised disposal of the above may have been via drains or on open ground within or adjacent to the site. ✓ Waste water containing chemicals from car washes may also cause contamination. ✓ Fuels such as petrol and diesel are highly mobile and have the potential to cause widespread contamination. ✓ Combustible materials may have been burned on-site along with waste oils. ✓ Used tyres and parts often present a disposal problem and may have been left on-site.	Low
List 2 National Incidents	16 -250m Various	Various	➤ There are several pollution incidents recorded within 250m of the site with the nearest being located approximately 239m to the north west of the site that pertains to atmospheric pollutants and effects. However, the incident was recorded as no impact to land and water and is unlikely to represent a source of contamination to the site. ➤ The remaining pollution incidents are also recorded as minor or as having no impact and are located a significant distance from the site. Consequently, they are also unlikely to have impacted the site.	Low

* DOE profiles give information on the contamination which may be associated with specific industries. The list is not exhaustive; neither does it imply that all these chemicals might be present at individual sites.

7.4.4 Excluded Potentially Contaminative Off-Site Sources

Those other potentially contaminative sources identified in previous sections are believed to be either of limited significance and / or located at a significant distance from the site that any potential contamination from these sources are highly unlikely to reach and have any detrimental effect to the site for the following reasons:

- Most of the off-site sources (including those potentially more contaminative areas of former ROF Wrexham) are either located downgradient of the site, or within areas where migration of contaminants within surface waters would be away from the site or to local drainage.
- Groundwater is also suspected to be influenced by topography but is further complicated by the presence of predominantly low permeability superficial deposits, with flow being dictated by the interconnected nature of any granular horizons. Ground gas pathways are also anticipated to be similarly influenced. For this reason, ground gas and groundwater pathways are also considered unlikely.
- For those more modern off-site sources extensive hardstanding areas negates most of the windblown pathways and with a prevailing wind direction from the south west it is unlikely that any soil derived dust would reach the site due to most of the off-site sources being located downwind of the site, or at such a distance that any soil derived dust is unlikely to reach the site.
- Those current and more modern land uses recorded within the immediate surrounding area and associated with Wexham Industrial Estate are unlikely to have resulted in any significant contamination due to modern working practices.

7.4.4 Chemical Testing

In consideration of all the above and the guidance contained in the appropriate DOE industry profiles and associated documents, it is therefore proposed to undertake extensive and specialist testing for the following determinands:

Arsenic, barium, beryllium, boron, cadmium, chromium, chromium (hexavalent), copper, cyanide, lead, mercury, nickel, selenium, vanadium, zinc, sulphate, pH, nitrite, nitrate, chlorides, ammonium, Total Petroleum Hydrocarbons (TPH) screen

followed by Speciated Aliphatic and Aromatic Total Petroleum Hydrocarbon Fractions (TPHCWG) where applicable, Speciated Polyaromatic Hydrocarbons (PAH), Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Benzene, Toluene, Ethylbenzene and Xylene (BTEX), Polychlorinated Biphenyls (PCBs), Total Phenols, Asbestos and Explosive Compounds; particularly those involved in cordite manufacture (e.g. nitroglycerine, nitrocellulose, nitroguanidine and picric acid).

It should be noted that the exact chemical suite should be modified / confirmed depending on the findings of any site investigation works.

7.5 Identified Pathways

The potential pathways identified from the desk study works are as follows.

Human Health Pathways

The pathways along which contamination could potentially reach the targets on site, during use and after completion of development works, are detailed in 'Updated Technical Background to the CLEA Model' (Environment Agency 2009), but can be summarised as follows:

- a) Ingestion of soil directly and indoor dust*.
- b) Inhalation of soil dust (indoor and outdoor).
- c) Dermal contact with soil (indoor and outdoor).
- d) Inhalation of soil vapours (indoor and outdoor).
- e) Oral background.
- f) Inhalation background.

** Treated as one pathway*

Ground Gas Pathways

The pathways along which ground gases could potentially reach the targets on site during use and after completion of development works are:

- a) Migration, ingress and accumulation. Migration by pressure driven and / or diffusive flow, predominantly via:
 - Possible permeable strata (e.g. granular pockets / lenses with a high degree of connectivity and more significant granular horizons with the Devensian Till) through matrix, fissures and discontinuities facilitating both vertical and lateral migration.
 - Man-made features (e.g. future, existing and historical foundations, buried services and other underground infrastructure / voids) facilitating both vertical and lateral migration.
 - Groundwater facilitating lateral migration; sometimes for great distances.
 - Possible low permeability strata or impermeable layers acting as barrier to vertical gas migration and resulting in lateral migration.

- b) Inhalation of vapours.

Controlled Waters Pathways

The pathways along which contamination could potentially reach identified receptors during use and after completion of development works are as follows:

- a) Vertical migration by dissolution into leachate / groundwater and subsequent transport through the ground via:
- Highly permeable strata with flow through matrix and / or discontinuities (e.g. granular pockets / lenses with a high degree of connectivity and more significant granular horizons with the Devensian Till).
 - Possible permeable strata (e.g. Landscaped Ground / Made Ground) with flow through matrix and / or discontinuities.
 - Discontinuities within low permeability deposits (e.g. fissures within Devensian Till).
 - Future, existing and historical foundations, underground infrastructure / voids, excavations and buried services.
 - Cracks within hardstanding areas.
- b) Lateral migration by dissolution into leachate / groundwater and subsequent transport through the ground via:
- Possible low permeability strata underlying permeable strata (e.g. natural cohesive deposits underlying permeable Landscaped / Made Ground) and acting as a barrier to vertical migration and resulting in lateral migration.
 - Future, existing and historical drainage / buried services and underground infrastructure / voids which could provide a conduit / pathway, with nominal diffusion and attenuation.
- c) Dissolution into leachate / surface waters and migration via surface water runoff / overland flow via:
- Hardstanding surfaces.
 - Possible low permeability strata at the surface (e.g. cohesive / low permeability Landscaped Ground).

7.6 Identified Receptors

The potential receptors identified from the desk study works are as follows.

Human Health Receptors

- a) Current site users
- b) End users
- c) Ground and construction workers
- d) The general public / adjacent site users

Ground Gas Receptors

- a) Current site and future human occupants
- b) Ground and construction workers
- c) The general public / adjacent site users
- d) On-site and off-site buildings and structures

Controlled Waters Receptors

- a) Secondary A Aquifer within the underlying Salop Formation that is present beneath the site.
- b) Secondary Undifferentiated Aquifer within the underlying Devensian Till that is present beneath the site.
- c) Surface water features including the small stream / drain that is located approximately 70m to the south east of the site, Redwither Brook and ultimately the River Clywedog.

Other Receptors

- a) Building fabric
- b) Services

7.7 Conceptual Models

Site conceptual models for human health, ground gas, controlled waters and building materials and services have been produced based on the possible sources, pathways and receptors identified in Sections 7.4, 7.5 and 7.6.

7.7.1 Conceptual Model for Human Health Risk Assessment

A site conceptual model in the form of a linkage table for the purposes of a preliminary risk assessment for human health has been produced and can be found in the table below:

Source	Potential Contaminants	Pathways	Receptors	Hazard Severity *1	Likelihood *2	Discussion	Risk
Former on and off-site ROF Wrexham	<i>Metals; TPH; PAH; SVOCs; VOCs; PCBs BTEX; Phenols; Explosive Compounds; Explosive Devices; Asbestos; Sulphate; Acids; Alkalies; Nitrite; Nitrate; Chlorides; Ammonium; Cyanide and those other contaminants outlined in sections 7.4.1 & 7.4.2</i>	Ingestion through the mouth of airborne dust and soil (indoor and outdoor)	Current site users	Effect on human health: Medium	Low likelihood	Receptor Sensitivity: Surrounding commercial / industrial land use. The most sensitive receptor is likely to be an adult working indoors. Hazard Severity / Presence: ➤ Several potentially contaminative sources identified with the highest risk pertaining to ROF Wrexham, which may have resulted in explosive contamination being present at the site (see Section 7.4.1). However, those ROF activities undertaken at the site and within the surrounding area have a low to moderate contaminative potential compared to other sections of ROF Wrexham. ➤ Those activities associated with ROF Wrexham with a higher contaminative potential are generally located downgradient of the site and / or within an area where any contamination is likely to have migrated away from the site. However, unrecorded and unauthorised disposal of contamination from other parts of ROF Wrexham may have occurred at the site (e.g. unrecorded burning grounds or wastes being dumped into ponds). ➤ Those explosive contaminants most likely to be present (Cordite, NG, NC, Picrite and possible explosive devices) represent a potential hazard to humans due to their explosive and highly flammable properties. Some of the explosive contaminants are also toxic to humans at concentrations below those for which an explosive hazard is present. ➤ Most of the explosive materials associated with Cordite manufacture and Cordite itself are environmentally persistent and relatively immobile. ➤ Site investigations undertaken approximately 610m to the north of the site recorded low concentrations of contaminants but only shallow testing was undertaken and explosive contaminants were not tested for. ➤ Site investigations undertaken at the former Firestone site approximately 370m to the south east of the site recorded 'contaminated' and 'highly contaminated' soils that included elevated metals, hydrocarbons, sulphate, toluene extractable material, pH, phenol and PAHs but these may be associated with the Firestone Factory itself. All explosive compounds tested for were below their detection limits but these tests were undertaken at shallow depth and following the remediation of the site. ➤ Due to the landscaping that is recorded to have occurred the soils are likely to have been reworked and this could have resulted in localised contamination from on and off-site sources being spread over a much larger area. Consequently, low concentrations of contamination may be present within the uppermost layers but contamination could be more widespread. ➤ During landscaping many of the more volatile contaminants are likely to have been lost to atmosphere or potentially migrated from site. However, due to the predominantly low permeability of the soils adsorption of contaminants is likely to have occurred and this would have reduced migration of many of the less mobile contaminants. ➤ While high permeability strata are anticipated to be present, they are unlikely to be interconnected at shallow depth, so the effects of migration and dilution are unlikely to be significant. ➤ High concentrations of contaminants may still be present in areas below the level of remixing (e.g. at the location of backfilled structures / excavations and within historic drainage). ➤ Asbestos fibres from demolished ROF structures may be bound within the soil due its predominantly clayey nature. ➤ Demolition arisings used to infill backfilled structures etc. may have been contaminated with explosives materials prior to backfilling as some explosives are particularly prone to contaminating porous surfaces such as building fabrics. ➤ Historic and current off-site sources are unlikely to have impacted the site either due to their low severity and that any contamination would have preferentially migrated downgradient to the south east or be captured in drainage. However, materials may have been windblown to the site or disposed of directly to the site during or after landscaping.	Low to moderate
On-site Landscaped Ground		Inhalation through the nose and mouth of airborne dusts and vapours (indoor and outdoor)					
Existing and Abandoned On-Site Drainage / Infrastructure		Absorption through the skin due to dermal contact with dust and soil					
On-site Historic Infilled Ponds							
Current and Historic Off-Site Sources							

Source	Potential Contaminants	Pathways	Receptors	Hazard Severity *1	Likelihood *2	Discussion	Risk
Former on and off-site ROF Wrexham On-site Landscaped Ground Existing and Abandoned On-Site Drainage / Infrastructure On-site Historic Infilled Ponds Current and Historic Off-Site Sources	<i>Metals; TPH; PAH; SVOCs; VOCs; PCBs BTEX; Phenols; Explosive Compounds; Explosive Devices; Asbestos; Sulphate; Acids; Alkalis; Nitrite; Nitrate; Chlorides; Ammonium; Cyanide and those other contaminants outlined in sections 7.4.1 & 7.4.2</i>	Ingestion through the mouth of airborne dust and soil (indoor and outdoor) Inhalation through the nose and mouth of airborne dusts and vapours (indoor and outdoor) Absorption through the skin due to dermal contact with dust and soil	Current site users (continued)	Effect on human health: Medium	Low likelihood	Receptor Presence: The site is easily accessible but any current site users are unlikely to spend a significant amount of time on-site and the frequency of visits are anticipated to be low as the site has no apparent use. Pathway Integrity: It is unlikely that current site users will come into contact with contaminated soils in the near surface during their visits. However, as potentially contaminated soils are present at the surface pathways are considered to be viable.	Low to moderate
			Ground & Construction Workers	Effect on human health: Medium	Likely	Receptor Sensitivity: Sensitive receptor in this instance would be an adult likely using personal protective equipment. Hazard Severity / Presence: As above for Current Site Users. Receptor Presence: Groundworkers likely to spend moderate periods of time on-site (typically an 8-hour work day) with a high frequency of visits until the work is complete. However, construction works are relatively short term in the grand scheme of things. Pathway Integrity: Acute interaction with soil and materials during ground works, enabling works, construction of foundations etc. so most pathways are feasible. Any asbestos fibres that are present could be released from the soil during earthworks and construction activities. Any potential significant contamination or explosive devices that are located at depth or within areas that have been backfilled (e.g. former buildings) may be encountered during excavations. Historic infrastructure possibly containing residual explosive compounds or contamination are most likely to be encountered or broken up during construction works.	Moderate
			Adjacent site users and general public	Effect on human health: Medium	Unlikely	Receptor Sensitivity: Surrounding commercial / industrial land use. The most sensitive receptor is likely to be an adult working indoors. Hazard Severity / Presence: As above for current site users. Receptor Presence: Adjacent site users likely to spend moderate periods of time off-site (typically an 8-hour work day) with a high frequency of visits. However, indoor working is envisaged. Pathway Integrity: As Landscaped Ground is present at the surface soil-derived dust may be windblown to off-site receptors but this is considered unlikely due to the predominantly clayey nature of the soils. In the short-term problems with soil derived dust are more likely during development of the site unless appropriate health and safety measures are undertaken (e.g. spraying down dust). Following development most pathways (expect for vapours) are anticipated to be negated/significantly reduced due to an increase in hardstanding areas. Potential pathways may remain for any areas of POS or soft landscaping. During construction works there could be risk to off-site users from an explosive incident.	Low
			Future site users	Effect on human health: Medium	Unlikely	Receptor Sensitivity: Industrial / Commercial land use so the most sensitive receptor would be an adult. Hazard Severity / Presence: As above for adjacent site users. Receptor Presence: Future site users likely to spend moderate periods of time on-site (typically an 8-hour work day) with a high frequency of visits. However, indoor working is envisaged. Pathway Integrity: Following development of the site there is expected to be an increase in hardstanding and indoor workings areas. Consequently, most pathways (expect for vapours) are anticipated to be negated/significantly reduced. Potential pathways may be present for any areas of POS or soft landscaping.	Low

*1 Considers both the potentially severity of the hazard and the sensitivity of the receptor. The most sensitive receptor / hazard has been used for the overall assessment.

*2 Considers both the presence of the hazard and receptor and the integrity of the pathway. The most likely hazard / pathways have been used for the overall assessment.

7.7.2 Conceptual Model for Ground Gas Risk Assessment

Potential on and off-site ground gas sources have been identified which could affect the proposed development. Those identified as the principal contaminative sources, based on their proximity and significance, along with the pathways and receptors outlined in sections 7.5 and 7.6, are recorded in the conceptual model below:

Source	Potential Ground Gases	Pathways	Receptors	Hazard Severity* ¹	Likelihood* ²	Discussion	Risk
Off-site Landfills	Methane / Carbon dioxide / Hydrogen Sulphide / Trace Gases	Migration Ingress and accumulation Inhalation	Current & future human occupants Ground and construction workers Building and structures	Effect on human health / Damage to Buildings: Medium	Unlikely	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration (e.g. explosion) are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: Comprises a number of relatively small landfills that are located approximately 978m to the north east of the site. Recorded to have received industrial and liquid sludge wastes between December 1953 and December 1983. Ground gas generation potential largely unknown due to the presence of industrial wastes but sludge wastes may have a moderate gas generation potential. May be past its primary methanogenic phase due to the age of the landfill. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time on-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated. Pathway Integrity: These landfills are located approximately 978m to the north east and downgradient of the site. Possible driving force for gas migration due to possible moderate ground gas generation potential. Predominantly low permeability of the natural superficial deposits will likely inhibit any lateral or vertical migration to the site. However, sand beds / lenses and fissures may provide pathways but limited interconnectivity is envisaged over such a distance. Groundwater flow is towards the south east and away from the site so any gas migration via groundwater is also considered unlikely.	Low
On-site Landscaped Ground / Made Ground Deposits	Methane / Carbon dioxide	Migration Ingress and accumulation	Current & future human occupants Ground and construction workers	Effect on human health / Damage to Buildings: Medium	Unlikely	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: The source is anticipated to be widespread but limited thicknesses envisaged and no degradable materials were noted during the previous SI works within the surrounding area, with low total organic contents (0.7 and 1.7%) recorded. However, thicker deposits may be present in areas of infilled excavations or backfilled structures and unrecorded degradable materials may be present. Ground gas generation is anticipated to be very low with a lack of driving force for gas migration. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time on and off-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated. Pathway Integrity: The source is anticipated to be widespread and located at the surface with no overlying low permeability soils so most pathways are viable; although ingress and accumulation is not considered a viable pathway for current site users.	Low
Historic On-site Infilled Ponds	Methane / Carbon dioxide	Inhalation	Building and structures Off-site buildings and structures	Effect on human health / Damage to Buildings: Medium	Unlikely	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: Unknown thickness and constituents of infilled material but anticipated to be associated with historic ROF Wrexham. Limited volume of infill is envisaged due to the size of the ponds. Any infill is at least 60 years old so a low ground gas generation potential is envisaged unless any degradable materials have remained dry. Ground gas generation is anticipated to be very low with a lack of driving force for gas migration. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time on and off-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated. Pathway Integrity: Overlying and surrounding low permeability soils anticipated to be present and likely inhibiting any lateral or vertical migration. Lack of driving force for gas migration anticipated due to low ground gas generation potential. However, pathways may be present during construction works and following development due to future foundations penetrating low permeability strata.	Low

Source	Potential Ground Gases	Pathways	Receptors	Hazard Severity* ¹	Likelihood* ²	Discussion	Risk
Residual hydrocarbon and VOC vapours associated with current and historic on-site activities	Hydrocarbons / VOC's / SVOC's	Migration Ingress and accumulation Inhalation	Current & future human occupants Ground and construction workers Building and structures Off-site buildings and structures	Effect on human health / Damage to Buildings: Medium	Unlikely	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: Historic on-site activities may have resulted in hydrocarbon or VOC contamination but these are not anticipated to be significant. Most historic contamination now <70 years old and due to the inherent mobility / volatility of most hydrocarbons / VOCs, the potential presence of pathways via permeable strata and the remixing of soils that likely occurred during landscaping; significant sources of vapours are unlikely to remain. However, sources of vapours may be present at the locations of backfilled structures / infilled excavations. No significant hydrocarbon or VOC concentrations noted for those SI works undertaken within the surrounding area. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time on and off-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated. Pathway Integrity: Any remaining source of vapours are likely to be overlain and surrounded by low permeability soils likely inhibiting any lateral or vertical migration. However, pathways may be present during construction works and following development due to future foundations penetrating low permeability strata.	Low
Historic Off-Site Infilled Ponds	Methane / Carbon dioxide	Migration Ingress and accumulation	Current & future human occupants Ground and construction workers	Effect on human health / Damage to Buildings: Medium	Unlikely	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: Numerous ponds located between 20 – 250m of the site. Unknown thickness and constituents of infilled material but anticipated to be associated with historic ROF Wrexham. Limited volume of infill is envisaged due to the size of the ponds. Any infill is at least 60 years old so a low ground gas generation potential is envisaged unless any degradable materials have remained dry. Ground gas generation is anticipated to be very low. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time on-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated. Pathway Integrity: While some of these ponds are located downgradient of the site the predominantly low permeability of the natural superficial deposits will likely inhibit any lateral or vertical migration to the site. However, sand beds / lenses and fissures may provide pathways but limited interconnectivity is envisaged at shallow depths. Lack of driving force for gas migration anticipated due to low ground gas generation potential.	Low
Residual hydrocarbon and VOC vapours associated with historic and current off-site activities	Hydrocarbons / VOC's / SVOC's	Inhalation	Building and structures	Effect on human health / Damage to Buildings: Medium	Unlikely	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: Historic off-site activities may have resulted in hydrocarbon or VOC contamination but these are not anticipated to be significant. Most historic contamination is now <70 years old and due to the inherent mobility / volatility of most hydrocarbons / VOCs, the potential presence of pathways via permeable strata and the remixing of soils that likely occurred during landscaping, significant sources of vapours are unlikely to remain. No significant hydrocarbon or VOC concentrations noted for those SI works undertaken within the surrounding area. However, sources of vapours may be present at the locations of backfilled structures / infrastructure. More recent VOC and / or hydrocarbon contamination may be present due to the current off-site sources identified but due to modern working practices this is not anticipated to be significant. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time on-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated.	Low

Source	Potential Ground Gases	Pathways	Receptors	Hazard Severity* ¹	Likelihood* ²	Discussion	Risk
(Continued) Residual hydrocarbon and VOC vapours associated with historic and current off-site activities	Hydrocarbons / VOC's / SVOC's	Migration Ingress and accumulation Inhalation	Current & future human occupants Ground and construction workers Building and structures	Effect on human health / Damage to Buildings: Medium	Unlikely	Pathway Integrity: The presence of any potential plumes and / or vapour migration beneath the site from historic sources is considered unlikely as most sources are / were located downgradient of the site or within an area where migration of contamination would be away from the site; assuming that sand beds / lenses are laterally interconnected. Any potential plumes and / or vapour migration beneath the site from those current and more modern sources is considered unlikely due to modern working practices; resulting in little contamination and that any contamination would be captured in local drainage rather than entering the ground. Any sources of vapours are likely to be overlain and surrounded by low permeability soils likely inhibiting any lateral or vertical migration. However, pathways may be present during construction works and following development due to future foundations penetrating low permeability strata.	Low
Solid Geology	Radon	Inhalation	Current & future human occupants Ground and construction workers	Effect on human health: Medium	Low	Receptor Sensitivity: For commercial / industrial buildings with large well-ventilated open spaces the consequences of gas migration are significantly reduced due to the lack of confined spaces. Increased severity for construction workers who may be working in confined trenches. Hazard Severity / Presence: The site lies within a Radon Affected Area where between 3 – 5% of properties are above the action level. Receptor Presence: Buildings and structures are permanent whereas human receptors are only likely to spend moderate periods of time off-site (typically an 8-hour work day) with a high frequency of visits; the exception being current site users where limited presence is anticipated. Pathway Integrity: Predominantly low permeability soils will likely inhibit any migration of radon gas from any concentrated radon sources located at depth (i.e. bedrock). However, soils may also constitute a radon source but again the low permeability of the soils will inhibit the migration of most radon gas.	Low to moderate

*¹ Considers both the potentially severity of the hazard and the sensitivity of the receptor. The most sensitive receptor / hazard has been used for the overall assessment.

*² Considers both the presence of the hazard and receptor and the integrity of the pathway. The most likely hazard / pathways have been used for the overall assessment.

7.7.3 Conceptual Model for Controlled Waters Risk Assessment

A site conceptual model in the form of a linkage table for the purposes of a preliminary risk assessment for pollution to controlled waters has been produced and can be found in the table below:

Source	Potential Pollutants	Pathways	Receptors	Hazard Severity* 1	Likelihood*2	Discussion	Risk
Former on and off-site ROF Wrexham	<i>Metals; TPH; PAH; SVOCs; VOCs; PCBs BTEX; Phenols; Explosive Compounds; Explosive Devices; Asbestos; Sulphate; Acids; Alkalis; Nitrite; Nitrate; Chlorides; Ammonium; Cyanide and those other contaminants outlined in sections 7.4.1 & 7.4.2</i>	Migration of water through ground (vertical and lateral)	Groundwater within Secondary A Aquifer (Salop Formation)	Effects to controlled waters: Medium	Current Development: Unlikely	Receptor Sensitivity: Not an overly sensitive receptor but an SPZ lies approximately 461m to the north west of the site. 9 No. groundwater abstraction licenses are recorded within 2km of the site. Hazard Severity / Presence: ➤ Several potentially contaminative sources identified with the highest risk pertaining to ROF Wrexham, which may have resulted in explosive contamination being present at the site (see Section 7.4.1). However, those ROF activities undertaken at the site and within the surrounding area have a low to moderate contaminative potential compared to other sections of ROF Wrexham. ➤ Those activities associated with ROF Wrexham with a higher contaminative potential are generally located downgradient of the site and / or within an area where any contamination is likely to have migrated away from the site. However, unrecorded and unauthorised disposal of contamination from other parts of ROF Wrexham may have occurred at the site (e.g. unrecorded burning grounds or wastes being dumped into ponds). ➤ Site investigations undertaken approximately 610m to the north of the site recorded low concentrations of contaminants but only shallow testing was undertaken and explosive contaminants were not tested for. ➤ Site investigations undertaken at the former Firestone site approximately 370m to the south east of the site recorded 'contaminated' and 'highly contaminated' soils that included elevated metals, hydrocarbons, sulphate, toluene extractable material, pH, phenol and PAHs but these may be associated with the Firestone Factory itself. Testing indicated that shallow perched waters within Made Ground are being impacted by arsenic, ammoniacal nitrogen and sulphate but these tests were undertaken at shallow depth and following the remediation of the site. ➤ Due to the landscaping that is recorded to have occurred the soils are likely to have been reworked and this could have resulted in localised contamination from on and off-site sources being spread over a much larger area. Consequently, low concentrations of contamination may be present within the uppermost layers but contamination could be more widespread. ➤ During landscaping many of the more volatile contaminants are likely to have been lost to atmosphere. ➤ High concentrations of contaminants may still be present in areas below the level of remixing (e.g. at the location of backfilled structures / excavations and within historic drainage). Receptor Presence: Groundwater depth unknown but is anticipated to be present at depths 40m. Pathway Integrity: While the Salop Formation is recorded to have a high leaching potential it is overlain by approximately 40m of predominantly low permeability superficial drift. While fissures and sand beds / lenses are present that could provide pathways to bedrock, it is unlikely that these are vertically interconnected and / or extend to bedrock. Even if pathways were present, due to the thickness of these deposits it is likely that significant dilution and attenuation would occur before the deeper groundwaters of the Secondary A Aquifer are reached.	Low
On-site Landscaped Ground							
Existing and Abandoned On-Site Drainage / Infrastructure					Post Development Site: Unlikely	Receptor Sensitivity: As above for current development. Hazard Severity / Presence: As above for current development. Receptor Presence: As above for current development. Pathway Integrity: As above for current development. However, if a piled foundation solution is required then pathways may be created but piled foundations to bedrock are considered unlikely. An increase in hardstanding is also envisaged reducing infiltration and vertical migration.	Low
On-site Historic Infilled Ponds							
Current and Historic Off-Site Sources							

Source	Potential Pollutants	Pathways	Receptors	Hazard Severity* 1	Likelihood*2	Discussion	Risk
Former on and off-site ROF Wrexham On-site Landscaped Ground Existing and Abandoned On-Site Drainage / Infrastructure On-site Historic Infilled Ponds Current and Historic Off-Site Sources	<i>Metals; TPH; PAH; SVOCs; VOCs; PCBs BTEX; Phenols; Explosive Compounds; Explosive Devices; Asbestos; Sulphate; Acids; Alkalis; Nitrite; Nitrate; Chlorides; Ammonium; Cyanide and those other contaminants outlined in sections 7.4.1 & 7.4.2</i>	Migration of water through ground (vertical and lateral)	Groundwater within Secondary Undifferentiated Aquifer (Devensian Till)	Effects to controlled waters: Mild	Current Development: Low Likelihood	Receptor Sensitivity: The receptor is not overly sensitive but is recorded to be an important source of groundwater within the district. 10 No. groundwater abstraction licenses recorded within 2km of the site. Hazard Severity / Presence: As above for Groundwater within Secondary A Aquifer. Receptor Presence: Shallow perched waters and deeper perched waters have been recorded in the area at depths of between 1.65m and 1.70m bgl, between 3.00m and 3.50m, between 4.80m and 6.50m bgl, between 9.20m and 10.20m, between 17.60m and 21.64m and between 24.69m and 26.82m, indicating that several perched water tables may be present. These perched water levels could vary seasonally but there is a low likelihood of interconnectivity. Pathway Integrity: Predominantly low permeability superficial deposits are envisaged at shallow depth but backfilled areas (e.g. backfilled structures) may have higher permeability or relict foundations could provide pathways to deeper water bearing layers. Sand channels / lenses are present within the Devensian Till at relatively shallow depth that could increase and have high permeability, respectively. Water bearing sand channels / lenses may be extensive and interconnected at shallow depth. However, vertical interconnectivity is considered unlikely.	Low
					Post Development Site: Low Likelihood	Receptor Sensitivity: As above for current development. Hazard Severity / Presence: As above for current development. Receptor Presence: As above for current development. Pathway Integrity: As above for current development. Potential for mobilisation of any contaminants during earthworks that may expose high permeability and water bearing layers. If a piled foundation solution is required then additional pathways may be present. However, an increase in hardstanding is also envisaged reducing infiltration and vertical migration.	Low
		Migration of water through ground (vertical and lateral) Near surface water run-off / overland flow	Surface water receptors (Stream / drain, River Clywedog)	Effects to controlled waters: Medium	Current Site: Unlikely	Receptor Sensitivity: The small stream / drains within the immediately surrounding area are not considered to be overly sensitive. The River Clywedog, is considered a sensitive receptor. Hazard Severity / Presence: As above for Groundwater within Secondary A Aquifer. Receptor Presence: Nearest surface water receptor is located 9m to the south east of the site. The River Clywedog is located approximately 470m to the south of the site. Pathway Integrity: Any significant contamination or contaminated waters are likely to be trapped on-site at the location of backfilled structures / excavations where they will be perched on low permeability Devensian Till. Vertical migration may occur where permeable backfill is present that intersects permeable layers within the natural Devensian Till. If these permeable layers are underlain by low permeability deposits lateral migration to receptors could occur if continuity exists but this is dependent on the orientation of any sand lenses / channels and their lateral interconnectivity. Due to the predominantly low permeability of the underlying soils it is likely that any near surface water run-off will migrate downgradient to the south east where it is likely to be captured within drainage. However, while these drains likely discharge to the surface water receptors noted there is limited potential for any leachable contaminants to be entrained within surface waters due to the anticipated low concentrations of contaminants at the surface. There is a limited distance between the source and the immediate receptor, but dilution and attenuation is likely to have occurred before any potentially contaminated waters reach the most sensitive receptor (River Clywedog).	Low
					Post Development Site: Low Likelihood	Receptor Sensitivity: As above for current development. Hazard Severity / Presence: As above for current development. Receptor Presence: As above for current development. Pathway Integrity: As above for current development. Potential for mobilisation of any buried contaminants or contaminated waters during earthworks that may expose high permeability and water bearing layers or result in surface water run-off to drains. However, due to the distance from the site to the most sensitive receptor attenuation and dilution is likely to occur. Due to an increase in hardstanding surface water run-off to drainage is considered a more viable pathway and any vertical migration will be largely negated.	Low to Moderate

*1 Considers both the potentially severity of the hazard and the sensitivity of the receptor. The most sensitive receptor / hazard has been used for the overall assessment.

*2 Considers both the presence of the hazard and the integrity of the pathway. The most likely hazard / pathways have been used for the overall assessment.

7.7.4 Conceptual Model for Building Materials and Services

Based on the identified potential sources of contamination and the anticipated ground conditions, aggressive contaminants with the ability to attack building materials (e.g. sulphates and acids) and services (e.g. PAH's) may be present on-site. Furthermore, there is evidence to suggest that nitroglycerine and Picrite may be capable of permeating plastic water supply pipes. Building materials and services are likely to come into direct contact with these contaminants through the soil or percolating waters.

During previous site investigation works potential contaminants with the ability to attack building materials and services were generally encountered at low concentrations with sulphate levels in the soil being indicative of Design Sulfate Class DS-1 and Aggressive Chemical Environment for concrete AC-1. However, elevated sulphate concentrations were noted in shallow perched groundwater within Made Ground Deposits.

Conversely, low concentrations of potential contaminants with the ability to attack building materials and services are envisaged at the site due to the landscaping and soil remixing that is recorded to have occurred following the demolition of ROF Wrexham. However, higher concentrations may occur at the locations of backfilled structures etc.

The identified potentially explosive contaminants and possible explosive devices could potentially affect both building materials / structures and services if an explosive event were to occur. However, this is only likely to occur following disturbance of the ground (e.g. through construction activities).

Consequently, a moderate risk is envisaged for building materials / structures and services during any ground / construction works that are undertaken at the site. Otherwise a low to moderate risk envisaged.

7.8 Environmental Risk Assessment Summary

Human Health

The desk study works indicate that overall the site poses a low to moderate risk to human health. This risk has been assigned on the basis that while potentially significant contaminative sources (e.g. ROF Wrexham) have been identified within the surrounding area; those ROF activities that were undertaken on-site and within the immediately surrounding area are considered to have a significantly reduced contaminative potential. Any contamination from more significant off-site sources is also likely to have migrated away from the site due to topographical effects. While significant harm could arise to receptors from a range of potentially toxic and / or explosive contaminants and devices that may be present at the site, there is a low likelihood of this harm occurring even over a long period of time and it is considered less likely in the short term.

Construction workers are anticipated to be most sensitive human health receptor on the basis that they will be subject to acute interaction with potentially contaminated soils and explosive contaminants during site development. Consequently, a moderate risk is envisaged as significant harm is possible in the short term. However, this increased risk can be mitigated by ensuring that appropriate work procedures are put in place, works are conducted with caution and that direct contact with potentially contaminated materials is avoided through the appropriate usage of personal proactive equipment (PPE).

For future site occupants the majority of pathways between source and receptor, with the exception of the soil vapour pathway, are anticipated to be either negated or significantly reduced resulting in a betterment to the site. Consequently, a low risk is envisaged as it is improbable that any significant harm would, occur even in the very long term.

Due to the uncertainty pertaining to any unrecorded activities that could occurred during the operation of ROF Wrexham (e.g. burning grounds, unauthorised disposal of wastes into features such as ponds and the filling of 1000lb shells) and

uncertainties following its demolition and remediation; there is the potential for unrecorded contamination to be present. Consequently, further investigative work should be undertaken to confirm the above regime and quantify any potential contamination / explosive contamination issues.

Ground Gas

Utilising the guidance stipulated in BS8485 (2015), BS8576 (2013) and CIRIA 665 (2007) the site is considered to be at a low level of risk from ground gases due to the very low ground gas generation potential for most of those identified sources, the very low probability of harm occurring to a receptor and the low sensitivity of the proposed development (e.g. commercial / industrial land use).

Consequently, using the approach outlined by Wilson et al. (2005) it is considered prudent to undertake ground gas monitoring for a period of at least 2 month, with at least 6 visits, to confirm this regime. However, it should be noted that the length and frequency of the ground gas monitoring may be subject to reassessment following site investigation works and the initial monitoring visits.

Alternatively, it may be also be feasible to utilise the approach outlined by Card and Wilson (2011) for low risk gas sites, as the site appears to have a very low risk of gas generation. However, the use of this method is dependent on the findings of the initial site investigation works.

It should be noted that as the site lies within an area where between 3 – 5% of homes are above the action level. Consequently, BR211 (2015) indicates that basic radon protective measures are necessary.

Controlled Waters

Despite evidence of impact to shallow perched waters within Made Ground being recorded during previous site investigation works a low risk is envisaged for controlled waters at this stage. This risk has been assigned on the basis that it is unlikely that any significant harm would occur, even in the very long term, as a significant thickness of predominantly low permeability superficial deposits are present overlying

the Secondary A Aquifer and that it is unlikely that any significant contamination would migrate to sensitive surface water receptors. While there is an increased likelihood of harm occurring to the Secondary Undifferentiated Aquifer it is not considered to be overly sensitive.

However, there is a risk that significant contamination with the potential to generate elevated leachable determinands may be present (e.g. at the location of backfilled structures) and sand pockets / lenses may be more extensive than envisaged. Consequently, further investigative work should be undertaken to clarify the risk. However, it is unlikely that extensive site investigation for controlled waters will be required.

Buildings and Services

The desk study works indicate that overall the site is at low to moderate risk from aggressive contaminants within the ground and groundwater that have the potential to attack building materials and services at the site. This risk has been assigned on the basis that potentially aggressive contaminants with the ability to attack building materials (e.g. sulphates and acids) and services (e.g. PAHs, nitroglycerine and Picrite) may be present on-site. A moderate risk is envisaged during construction works due to the explosive risk to adjacent building materials and services.

7.9 Geotechnical Risk Assessment Summary

It is a requirement of the National Planning Policy Framework (NPPF) Clause 121 for a site potentially at risk from ground instability to be assessed. Consequently, consideration has been given to the risk of potential causes of ground instability arising from the ground conditions that are present at the site.

Those risks pertaining to ground instability that have been identified from the desk study information have been outlined in the table on the following pages.

It should be noted that this list is not exhaustive and has only been included to provide preliminary guidance on the most likely geotechnical hazards that are present at the site. Any recommendations / comments made are based on publicly available data and are of a general / conservative nature in the absence of site-specific information. Consequently, any comments should be treated as preliminary until such a time as the ground conditions have been clarified in more detail following suitable site investigation works.

Potential Hazard	Description / Outline of Hazard	Pertinent Site-Specific Details	General Recommendations / Considerations	Risk
Expansive Soils (Shrink / Swell)	Some types of ground (e.g. clay soils) can change volume due to changes in moisture content induced by weather variations (e.g. drought), vegetation (e.g. growth or removal of trees) or man-made activities (e.g. changes to local drainage or leakage from water pipes). This shrink / swell behaviour typically causes significant ground movement to a depth of approx. 3m (although depths of 6m bgl have been reached in London Clay) potentially damaging building foundations, externals, pipes or services by differential movements.	➤ The natural Devensian Till within the Wrexham area is recorded to have a low to intermediate, sometimes high plasticity and is typically of low to intermediate shrinkage potential. However, Laminated Clay Till is recorded to be well developed around the Wrexham Industrial Estate and these clays are more susceptible to shrink / swell (typically of intermediate plasticity and of medium shrinkage potential). ➤ Previous site investigation works in the surrounding area have revealed that the cohesive natural Glacial Till deposits are of intermediate to high plasticity and of medium shrinkage potential. As indicated by the above this is more typical of Laminated Clay Till, which is also indicated by nearby BGS Borehole logs. However, limited testing was undertaken. ➤ Several mature trees are located along the sites south western, south eastern and north eastern boundaries. A few scattered mature trees were also located across the site prior to recent site clearance. ➤ Desiccation may have occurred around trees potentially leading to swelling following an increase in soil moisture content (e.g. removal of trees). ➤ Low moisture contents recorded within the top 5m of the laminated clay tills indicate that in the area these deposits may be desiccated down to at least 5m. Consequently, they could be susceptible to swelling with increases in moisture content. ➤ The plasticity and shrinkage / volume change potential of the Landscaped Ground that is recorded beneath the site is unknown and could vary widely. However, if they comprise reworked natural deposits then values could be like that for the Devensian and Laminated Tills.	✓ Shrink / swell tests may be required to assess the volume change potential of the soils at the site. ✓ Local deepening of shallow foundations near to trees may be required. ✓ Consideration may need to be given to external areas and services; especially if trees are to be planted. Soil stabilisation and / or water control methods may be required to avoid differential movements if expansive soils cannot be avoided or removed. Alternatively, a design for low strength and regular maintenance may be required. ✓ Do not plant trees with high soil moisture demands near to buildings.	Moderate
Compressible Soils	Some types of soft superficial deposits may undergo volume reduction over time if loaded or if the groundwater level changes. This compression is due to water expulsion (primary consolidation) followed by restructuring (secondary consolidation) that may result in excessive settlement of the ground and damage to overlying buildings, externals, pipes or services by differential settlement.	➤ The natural Devensian Till within the Wrexham area is recorded to have a low to high compressibility. However, if laminated clay till is present, as indicated by previous site investigation works and BGS Boreholes, then these deposits are typically recorded to be of medium compressibility. ➤ The compressibility of the Landscaped Ground is unknown and could vary widely. However, if they comprise reworked natural deposits then values could be like that for the Devensian and Laminated Tills. ➤ If the natural Tills are desiccated at the surface then this may reduce compressibility somewhat due to low moisture contents. ➤ Compressible soils may be present at the location of the possible infilled ponds that are located on-site.	✓ Specialist consolidation / settlement tests using laboratory and field methods may be required to estimate the degree and rate of settlement. especially if high foundation loads are envisaged. ✓ Consideration may need to be given to external areas and services if the natural superficial deposits are found to be compressible. Soil stabilisation, ground improvement, geosynthetics or lightweight fill may be required to avoid settlement. ✓ If the natural superficial deposits are found to be compressible then large differential loadings of the ground should be avoided.	Moderate

Potential Hazard	Description / Outline of Hazard	Pertinent Site-Specific Details	General Recommendations / Considerations	Risk
Groundwater	Nearly all geotechnical hazards are linked in some way with water or groundwater (e.g. increased pore water pressure may cause slope failure and decreased pore water pressure may cause subsidence in clays). However, specific problems related to groundwater are the potential for water ingress into open excavations that may result in instability and collapse. Capillary rise in embankments may also cause instability problems.	➤ Previous SI works within the surrounding area have recorded perched water within permeable Made Ground deposits. These perched waters may be present on-site in areas that have been backfilled (e.g. cuttings, former structures and infilled ponds). ➤ Those BGS boreholes located on-site and within the immediately surrounding area indicate that shallower groundwater within the natural superficial deposits may be present beneath the site at depths of between 2.40m and 3.50m. ➤ Within the BGS Boreholes artesian conditions were also indicated and this coincides with the springs noted on the historical maps and the artesian conditions recorded within the sands and gravels beneath the Wrexham Industrial Estate. ➤ While artesian groundwater within the natural Devensian Till is generally encountered at depth within the surrounding area it may be present at a shallower depth beneath the site due to the presence of significant granular beds / lenses at shallower depth and the moderate to fast inflows noted from those BGS boreholes located on-site and within the immediately surrounding area. ➤ Deeper groundwater within the underlying solid geology was not encountered within any of the boreholes reviewed and is anticipated to be located at a significant depth beneath the site (<40m). ➤ Due to seasonal variations groundwater may be encountered at shallower depth due to prolonged periods of rainfall. However, this would be dependent on the extent and interconnected nature of any permeable layers within the natural Glacial Till.	✓ There may be a requirement for localised temporary works in the form of construction dewatering / exclusion techniques (e.g. cut-off walls) during excavation of any service trenches, mass excavations or excavations for foundations (depending on the foundation type selected). ✓ Monitoring wells should be installed within boreholes with subsequent groundwater monitoring to further quantify the risk. ✓ Artesian groundwater may cause problems for intrusive investigations (e.g. boreholes) and / or any piling works.	Moderate
Running Sand	Some types of ground (e.g. loose sand) can become fluidized by water flowing through them. This occurs when the pressure of the water filling the spaces between the sand grains reduces the contact between the grains and they are carried along by the flow. These conditions typically occur where excavations in loose sand go below the water table, where springs occur at the base of a sand outcrops, around leaking drains or mains water supply pipes or if sand is vibrated (e.g. liquefaction). Such sands can 'run', removing support from overlying buildings, externals and services causing potential damage.	➤ The silts and sands of the natural Devensian Till within the Wrexham area are usually water bearing and are known to develop running conditions; particularly along spring lines where they are underlain by impermeable materials. Springs are recorded in the area on historical maps. ➤ Those BGS boreholes located on-site and within the immediately surrounding area indicate that considerable thicknesses of loose, water bearing, fine to medium sands and silts with running conditions may be present at shallower depth (approximately 3 – 5m bgl) beneath the site. ➤ As noted above artesian pressures are also indicated on the BGS Borehole Logs and this constant upward velocity of flow is likely to provide the necessary fluidisation to allow running sand conditions to occur. ➤ The BGS borehole logs indicate that these water bearing sands and silts also contain layers of clay / silt. This difference in permeability between the layers can also contribute to running sand conditions. ➤ Leaking drains or water mains may be present beneath or within the vicinity of the site that may also provide the necessary flow to induce running sand conditions.	✓ Support may be required in open excavations. ✓ Avoid large amounts of water entering the ground through pipe leakage or soakaways. ✓ Do not dig deep holes in saturated sands without technical advice. ✓ Where running sand deposits are significant ground improvement techniques may be required for foundations and externals / services. Flexible foundations and super structures may be applicable for smaller, lower costs structures.	Moderate

Potential Hazard	Description / Outline of Hazard	Pertinent Site-Specific Details	General Recommendations / Considerations	Risk
Made Ground	Made Ground may settle variably, have poor bearing capacity and may suffer significant movements due to cases other than imposed loading (e.g. self-weight settlement) that may be problematic for foundations, externals and infrastructure elements. Other problems associated with some Made Ground include contamination, spontaneous combustion and the emission of gas.	➤ Due to the historical development on-site, a significant thicknesses of Landscaped Ground may be present at the site; particularly at the location of backfilled below ground structures. ➤ Previous site investigation works within the surrounding area recorded a significant thickness (<2.80m) of Made Ground at the location of former backfilled structures. However, the area on-site covered by former structures is limited (e.g. confined to the boundaries). ➤ It is unknown to what extent the Landscaped Ground was engineered, if any, and therefore it should be treated as suspect until proved otherwise.	✓ Important to further determine the nature and thickness of any Landscaped Ground and / or Made Ground as this would determine the type of foundation solution. ✓ Excavations within non-engineered Made Ground may be unstable, and support may be required. ✓ If significant Made Ground is present and it is selected as a founding strata ground improvement may be required to improve the load carrying characteristics. ✓ Piled foundations and / or suspended floors may be required for structures that are sensitive to small movements if significant Made Ground Deposits are present.	Low to moderate
Aggressive Ground	Acidic ground and sulphate may attack the concrete and steel used in foundations and react with aggregates. Sulfur is widespread in rocks and occurs in two principal forms; an oxidised state as sulphate (e.g. gypsum) or in a reduced state as sulphide (e.g. pyrite). Other forms can occur in special circumstances. The oxidation of pyrite and other sulphides can also occur due to geotechnical activities. This can lead to the generation of high concentrations of sulphate and low pH that attacks construction materials and may lead to the precipitation of gypsum resulting in the heave of foundations and floor slabs	➤ Previous site investigation works encountered elevated pH and sulphate in soils and elevated concentrations of sulphate in shallow groundwater. However, these elevated concentrations may be associated with historic site uses that were not recorded on-site (e.g. Firestone Factory). ➤ Those identified potentially contaminative activities at ROF Wrexham involved mineral acids and processes that produced acid effluents. However, the site is suspected to be remote from any processing areas but unrecorded on-site disposal may have occurred or leaking pipes may have been present beneath the site. ➤ The natural superficial deposits beneath the site are not anticipated to contain significant concentrations of pyrite, although high concentrations can occur within overconsolidated Glacial Till; especially if they are derived from pyrite rich strata. However, this is not anticipated to be the case on-site. ➤ Significant contents of pyrite are not anticipated for the Landscaped Ground that may be present on-site as they are anticipated to be derived from natural superficial strata. However, colliery soil from the nearby coalfield may have been utilised in places and this could be pyrite rich.	✓ Assessment of sulphate / sulphide contents and pH of the soil and groundwater should be undertaken to further clarify the risk. ✓ If aggressive contaminants are identified then concrete may need to be designed to withstand aggressive ground. ✓ Specialist testing may be required to ascertain the heave potential of any soils / stabilised soils or the degradation potential of any fill materials. ✓ Potentially aggressive ground exceeding the limiting values for backfill to structural metallic elements may not be permitted as backfill to reinforced soil, anchored earth or corrugated steel buried structures (excluding manholes and drain covers). ✓ Pyrite oxidation can be triggered by mixing susceptible materials with lime or cement resulting in high pH that can lead to the expansion of some sulfates that cause heave of stabilised soils.	Low to moderate

Potential Hazard	Description / Outline of Hazard	Pertinent Site-Specific Details	General Recommendations / Considerations	Risk
Obstructions	Man-made obstructions in the form of buried structures or parts of structures are commonly encountered on brownfield sites and these can be particularly hazardous if they contain voids. Obstructions may delay site investigation works and affect subsequent design and construction by creating obstructions to excavations and / or the chosen foundation solution, by acting as 'hard spots' in the ground and increasing variability within the ground. Obstructions can be solid or contain space filled by other solids, liquids or gases. Damage to a buried structure may create hazards by instigating collapse or by releasing these liquids or gases leading to other issues.	➤ Due to the historical development that is recorded to have occurred on-site (e.g. ROF Wrexham) there is a possibility that significant obstructions may be present beneath the site; particularly at the location the former ROF structures, infrastructure and areas of backfill. ➤ Previous site investigations within the area have recorded obstructions pertaining to former ROF buildings and infrastructure and there are indications that following the demolition of ROF Wrexham the buildings were only demolished to ground level and that subterranean features (e.g. basements) were either left in-situ or backfilled. ➤ Consequently, numerous subterranean features may be present beneath the site and this could include concrete slabs / walls / foundations, potential basements, drains and other services, underground tunnels, roadways and railway tracks.	✓ Important to determine if obstructions are present and to what extent as hard digging and / or breaking out may be required, which could impede site investigation works or slow down an earthworks exercise, if not factored into the timings. ✓ Probing works, geophysical works and / or intrusive site investigation works can provide an indication as to the presence and extent of any obstructions. ✓ Easements may be required for obstructions that are still in use (e.g. major sewers, tunnels or pipelines) but no significant infrastructure is envisaged.	Low
Collapsible Soils	Some types of ground (e.g. fine grained loessic soil) can collapse due to increased loads (induced by buildings or road traffic) and / or more commonly the addition of water (e.g. leaking pipes, poor drainage and groundwater recharge) causing the soils to become saturated for the first time. The volume reduction associated with this collapse may be up to 15% of the soil thickness. This is followed by a rapid reduction in volume of the ground which may cause damage to overlying buildings, externals, pipes or services by sudden or differential settlement.	➤ Natural soils susceptible to collapse are unlikely to be present beneath the site due to the processes that have resulted in their deposition (i.e. created by the action of ice and meltwater) and resulting lack of an open metastable structure. ➤ Some of the Glacial silts noted on the BGS Borehole logs may be more susceptible to collapse but again due to the style of deposition, depth, thickness and the presence of perched water tables within the Till; this is considered unlikely. ➤ Landscaped Ground and / Made Ground may be susceptible to collapse but this is dependent on the thickness, grading and level of compaction / engineering employed. ➤ Local collapses may occur if voids from infrastructure or previous site use (e.g. ROF Wrexham) are present beneath the site.	✓ No special ground investigation or construction methods are envisaged. ✓ Probing works, geophysical works and / or intrusive site investigation works can provide an indication as to the presence and extent of any voids are present beneath the site.	Low

7.10 Mining Assessment

As outlined in Section 6.6 while the site lies within a Coal Authority Coal Mining Reporting Area, with numerous other types of mining recorded within the district. However, most of the mineral resources lie beneath a thick cover of superficial drift deposits (approximately 40m) and / or are located at considerable depth below rockhead and / or have been undertaken a considerable distance away from the site.

Furthermore, there is also limited evidence to suggests that any other types of mining or historic surface excavations (e.g. brick clay or sand and gravel workings) have occurred at the site. However, a suspected gravel pit was located approximately 300m to the south east of the site, but this if of limited size and extent.

Consequently, the risk posed from coal and other forms of mine workings is considered to be very low.

It should be noted that unrecorded surface extractions may have been undertaken at the site and subsequently backfilled. In particular this pertains to any sand and gravel and / or clay pits.

8.0 **FURTHER WORKS**

As a result of this Phase 1 Geo-Environmental Desk Study Assessment it is recommended that a Phase 2 Intrusive Geo-Environmental Ground Investigation is undertaken to determine the concentrations of probable contaminants in the ground and groundwater (by obtaining samples of soil and groundwater and undertaking chemical composition tests, using an MCERTS accredited laboratory, to determine contamination levels) and to further investigate those potential geotechnical abnormalities identified as part of the desk study works.

Due to the risk of explosives and explosive devices to be present at the site, any future site investigation works should be undertaken in accordance with the Environment Agency R&D Technical Report P5 – 042/TR/03.

As outlined by the above document it is recommended that a phased approach to the site investigation works is adopted, with trial pitting works being undertaken prior to any borehole construction to demonstrate that there is a low explosive contaminant risk before other intrusive site investigation methods are undertaken.

Initial Site Investigation

The initial site investigation works should be undertaken on both a spatial and targeted basis to provide an assessment in terms of both environmental and geotechnical site parameters. These initial site investigation works should comprise mechanically excavated trial pits to determine the following:

- To establish the thickness, extent and characteristics of the underlying Landscaped Ground / Made Ground and natural superficial deposits beneath the site.
- Allow for the identification of any explosive devices and / or pockets of highly concentrated explosive contamination.
- Allow for the collection of solid and water samples for environmental chemical and explosives testing – as detailed in Section 7.4.
- Allow for in-situ and ex-situ hand shear vane testing of any underlying cohesive materials;

- To clear locations for future shell and auger boreholes, which will be undertaken primarily for geotechnical purposes.
- Targeted testing of soils and perched waters within infilled ponds / excavations, backfilled structures and historical drainage / infrastructure to establish if any significantly elevated concentrations of contaminations are present below the level of soil-remixing that is recorded to have occurred across the site due to landscaping.
- Spatial testing within the Landscaped Ground that is recorded across the site to establish if contamination is present and, if so, to establish that low concentrations are present due to soil-remixing.
- Spatial testing within the natural superficial deposits and, if required, deeper perched groundwaters to establish if there is an absence of contamination and hence prove the integrity of the pathways discussed in the conceptual models.
- Establish the extent to which sand pockets / lenses are present within the underlying natural Devensian Till both for geotechnical and environmental purposes.

Subsequent Works

Following on from the initial works more detailed geotechnical site investigation works should be undertaken to investigate those potential geotechnical abnormalities identified as part of the desk study works. These site investigation works should comprise of shell and auger boreholes for the following purposes:

- To establish the thickness, extent and characteristics of the natural superficial deposits beneath the site;
- To undertake in-situ geotechnical testing (e.g. standard penetration tests and hand shear vane tests) within the various strata present beneath the site;
- To obtain additional samples for further environmental chemical and geotechnical laboratory testing;
- To obtain undisturbed high-quality samples for specialist geotechnical laboratory testing;
- To allow for the installation of monitoring instrumentation (e.g. ground gas and groundwater monitoring wells) and the collection of groundwater samples.

- To further establish the extent to which sand pockets / lenses are present within the underlying natural Devensian Till; both for geotechnical and environmental purposes.
- Establish the volume change potential and the compressibility of any underlying natural cohesive superficial deposits.
- Establish the prevalence of any perched waters and deeper groundwater tables beneath the site and any associated running sand and / or artesian conditions.

Sampling

As samples could potentially contain explosive contaminants it is essential that all samples taken from the site should be considered potentially explosive until proven otherwise. Samples should also be taken in general accordance with current good practice and paying particular attention to the following:

- Samples should be taken using non-sparking implements only;
- Samples should be placed in amber glass jars with PTFE (Teflon) liners and using a sealing lid suitable for use with primary explosives;
- Samples suspected of or to be tested for explosives contamination should be tested prior to transport on the public roads, unless special exemption has been granted by HM Inspectorate of Explosives. Samples which are suspected or proved to contain >1% by weight of explosives may require a licence for storage and transportation;
- All sample packaging of such soil samples should comply with the Packaging of Explosives for Carriage Regulations and the Classification and Labelling of Explosives Regulations;

To avoid the administrative difficulties of transporting soils suspected to contain explosive contaminants consideration should be given to on-site screening by appropriate methods to demonstrate that samples do not present an explosives risk during transportation.

Proprietary test kits should only be used if these have been proven on the soil and contaminant mix found on the site and found to meet the screening objective. Many

test kits are compound specific and therefore may not be appropriate for screening for the range of explosives suspected.

Other Considerations

Site investigation works should not be undertaken until the risk posed from potential UXO at the site has been fully assessed and / or mitigating measures have been put in place as outlined in CIRIA C681.

Due to the risk of finding explosive contaminants or devices on-site, procedures should be documented in detail before any works are undertaken and a suitable method statement and risk assessment prepared in advance of any works. These documents should be produced by a competent person / persons trained and experienced in Explosives Safety Management.

Prior to works commencing and during the works full safety awareness briefings should be undertaken to inform all site personnel of the previous site use, the associated explosive risks, appropriate working procedures and the correct action to take in the event of an emergency or explosive incident.

The site investigation works should be supervised by a competent person / persons trained and experienced in Explosives Safety Management and in the recognition of explosive devices. If any such devices are encountered during site investigation works, work should cease immediately and the appropriate action taken.

All samples that are to be tested that are suspected of containing potentially explosive contamination should undergo analysis for explosive content prior to any further laboratory analysis. This should be undertaken by a suitably accredited explosives laboratory.

If separate laboratories are proposed for explosives and conventional testing, then the laboratory conducting the explosives analysis must advise the conventional laboratory on safe testing methods based on any identified explosive content.

Appropriate time should be allowed for this liaison between laboratories, before the investigation is carried out.

Samples containing explosives or other hazardous materials will require special disposal in accordance with the EPA duty of care.

Dealing with explosives is a specialist service and it is generally appreciated that most insurance policies specifically exclude work with explosives.

It is recommended that that full-service plans are obtained for the site prior to any intrusive site investigation works and construction activities.

Care should be taken in regard to the locations of trial pits to ensure that the ground is not disturbed at or close to the intended foundation locations as these types of excavations may result in soft spots.

It should be noted that following the site investigation works further exploratory holes may be required based on the findings (e.g. to delineate areas of identified contamination and / or areas of instability).

9.0 **RECOMMENDATIONS**

- 9.1 The desk study works indicate that overall the site poses a low to moderate risk to human health. This risk has been assigned on the basis that while potentially significant contaminative sources (e.g. ROF Wrexham) have been identified; those ROF activities that were undertaken on-site are considered to have a reduced contaminative potential. While significant harm could arise to arise to receptors from a range of potentially toxic and / or explosive contaminants and devices that may be present at the site, there is a low likelihood of this harm occurring even over a long period of time and it is considered less likely in the short term; the exception being construction / ground workers who are believed to be at a moderate risk. Consequently, further investigative work should be undertaken to confirm the above regime and quantify any potential contamination / explosive contamination issues.
- 9.2 The desk study works indicate that overall the site poses a low risk to controlled waters. This risk has been assigned on the basis that it is unlikely that any significant harm would occur, even in the very long term, as a significant thickness of predominantly low permeability superficial deposits are present overlying the Secondary A Aquifer and that the most sensitive surface water receptor is located a significant distance away from the site. While there is an increased likelihood of harm occurring to the Secondary Undifferentiated Aquifer it is not considered to be overly sensitive. However, there is a risk that significant contamination with the potential to generate elevated leachable determinands may be present and sand pockets / lenses may be more extensive than envisaged. Consequently, further investigative work should be undertaken to clarify the risk. However, it is unlikely that extensive site investigation for controlled waters will be required.
- 9.3 On the basis of the desk study works undertaken, the site is considered to be at low risk from ground gases due to the very low ground gas generation potential for most of those identified sources, the very low probability of harm occurring to a receptor and the low sensitivity of the proposed development (e.g. commercial / industrial land use). Consequently, it is considered prudent to undertake ground gas monitoring for a period of at least 2 months and incorporating 4 visits to confirm this regime.

Alternatively, it may be also be feasible to utilise the approach outlined by Card and Wilson (2011) for low risk gas sites, as the site appears to have a very low risk of gas generation. However, the use of this method and / or the length or frequency of the monitoring works are dependent on the findings of the initial site investigation works. The site lies in an area where between 3 – 5% of homes are affected by radon or above the Action Level. Consequently, basic radon protection measures are required.

9.4 The site lies within a Coal Authority Coal Mining Reporting Area, with numerous other types of mining recorded within the district. However, most of the mineral resources lie beneath a thick cover of superficial drift deposits (approximately 40m) and / or are located at considerable depth below rockhead and / or have been undertaken a considerable distance away from the site. Furthermore, there is also limited evidence to suggests that any other types of mining or historic surface excavations (e.g. brick clay or sand and gravel workings) have occurred at the site. Consequently, the risk posed from coal mining or other forms of mine workings are considered to be very low.

9.5 Due to those environmental and geotechnical requirements identified, site investigation works should be undertaken in order to determine the ground conditions and the concentrations of potential contaminants with a greater degree of certainty, to either confirm the identified risk to receptors and / or allow for a refined assessment to be undertaken; but to also allow for the preliminary and / or detailed design of the proposed foundations, drainage, services and immediate external areas to be undertaken. These site investigation works should include sufficient trial pits and shell and auger boreholes with appropriate testing to investigate those potentially contaminative sources and geotechnical abnormalities identified. Due to the potential for explosives and explosive devices to be present at the site, any future site investigation works should be undertaken in accordance with the Environment Agency R&D Technical Report P5 – 042/TR/03 and supervised by a competent person / persons trained and experienced in Explosives Safety Management and in the recognition of explosive devices.

- 9.6 As the site was a former military site investigation works should not be undertaken until the risk posed from potential UXO at the site has been fully assessed and / or mitigating measures have been put in place as outlined in CIRIA C681. A Detailed Unexploded Ordnance Risk Assessment will be required for this assessment and it is recommended that this assessment is undertaken before site investigation works are to commence.
- 9.7 Due to the potential for explosives and explosive devices to be present at the site it is recommended that appropriate procedures (e.g. full safety awareness briefings) are put in place and documented in detail before any works are undertaken and a suitable method statement and risk assessment prepared in advance of any works. These documents should be produced by a competent person / persons trained and experienced in Explosives Safety Management.
- 9.8 All samples taken from the site with a known potential for explosive contamination should be considered potentially explosive until proven otherwise. Appropriate handling and transportation of such samples will therefore be required and should follow the Road Traffic (Carriage of Explosives) Regulations. Consideration should be given to on-site screening by appropriate methods to demonstrate that samples do not present an explosives risk during transportation.
- 9.9 All samples that are to be tested that are suspected of containing potentially explosive contamination should undergo analysis for explosive content prior to any further analysis. This should be undertaken by a suitably accredited explosives laboratory. If separate laboratories are proposed for explosives and conventional testing, then the laboratory conducting the explosives analysis must advise the conventional laboratory on safe testing methods based on any identified explosive content. Appropriate time should be allowed for this liaison between laboratories, before the investigation is carried out.
- 9.10 Samples or earthworks materials containing explosives or other hazardous materials may require special disposal in accordance with the EPA duty of care.

- 9.11 If the results from the Phase 2 environmental site investigation works identifies a potential risk and / or a requirement for further detailed site – specific assessment, a Phase 3 environmental investigation and / or a remedial strategy (informing on potential remediation solutions) may be required.
- 9.12 The nature and extent of the proposed targeted chemical and environmental testing should be confirmed, if time / commercial constraints allow, with the relevant Local Authority Environmental Health Officer and the Environment Agency prior to undertaking works on site. Proceeding without agreement between regulatory authorities may result in further assessment being required.
- 9.13 If any additional visual or olfactory evidence of contamination is encountered during the development of the site, then the Local Authority Environmental Health Officer and Environment Agency should be contacted immediately in order to agree any necessary remediation measures.
- 9.14 It is recommended that that full-service plans are obtained for the site prior to any intrusive site investigation works and construction activities. There may also be a requirement for a GPR survey of the site to be undertaken if unrecorded services are anticipated to be present.