

Hydrock 

Knutsford Town Centre Feasibility Studies

Phase 1 Ground Conditions Desk Study Report

For Knutsford Town Council

Date: 12 June 2024

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Executive summary

<i>Site information and setting</i>	
Objectives	The works have been commissioned to ascertain the viability and costs of the potential development of the site as a multi-storey car park.
Client	Knutsford Town Council.
Site name and location	Tatton Street Car Park. Tatton Street, Knutsford WA16 6AG.
Proposed development	Hydrock understands that the proposed development is to comprise a multi-storey car park. The proposed development layout has yet to be finalised.
Site description	The site is currently a car park accessed from Tatton Street to the east. The car park is surfaced with asphalt which is generally in good condition. Mature trees are present on the along the site boundaries.
<i>Desk study summary</i>	
Topography	The site gently slopes down from the north west to the south east from approximately 62m to 59m above Ordnance Datum (OD).
Hydrology	The closest surface water feature is the River Lily, approximately 190m east of the site. The River Lily flows north to Tatton Mere.
Site History	<p>There was a gas works present on site from the earliest available mapping in 1876, including Gas Holder No.1 and No.2, Purifiers, Oxide Store and Canteen. The Gas works ceased use in the 1950s with all above ground infrastructure demolished by 1974. The wider Knutsford Gas Works to the south west included the retort houses, coal stores, scrubbers, exhausters, workshops and tar and liquor wells.</p> <p>From early 1970s the site is shown as a car park with an abattoir to the south east of the site. From the early 2000s the site is shown to solely be a car park with no structures present.</p>
Geology	<p>Superficial: Glaciofluvial Deposits.</p> <p>Solid: Northwich Halite Member.</p>
Natural geological hazards	<p>Trees and hedges are present along the site boundaries and the shallow cohesive soils of the Glaciofluvial Deposits may be subject to shrink or swell following the removal or planting of trees.</p> <p>The environmental report indicates there is a very significant risk from soluble rocks with a high possibility of localised subsidence or dissolution-related degradation of the bedrock. There is potential for voids to migrate to the surface forming sinkholes associated with historic brine pumping. As part of the ground investigation the presence of absence of dissolution features should be confirmed and scope of investigation agreed with the Brine Board.</p> <p>Due to the presence of Glaciofluvial deposits at the site and unknown groundwater levels within the superfcials there is a risk of running sands at the site.</p>

<p>Anthropomorphic geotechnical hazards</p>	<p>Variable heterogeneous Made Ground deposits associated with the former gas works on site present a geotechnical hazard. Composition and depth of Made Ground should be determined as part of an intrusive investigation.</p> <p>The Made Ground may contain obstructions associated with historical below ground structures or demolished buildings,</p>
<p>Hydrogeology</p>	<p>Shallow groundwater is likely to be present within the Glaciofluvial deposits. There is potential for discontinuous/local perched groundwater within the Made Ground.</p> <p>The shallow groundwater will likely flow towards the River Lily located 190m east. However, the shallow groundwater is unlikely to be in direct hydraulic continuity with the River Lilly, the presence of the low permeability Glacial Till to the east will likely act as a confining unit.</p>
<p>UXO risk</p> <p>Previous Ground Investigations</p>	<p>A non-specialist UXO assessment indicates a low bomb risk.</p> <p>The previous ground investigations confirmed the following:</p> <ul style="list-style-type: none"> » Deep Made Ground was encountered within Holder No1, containing tar odours and visual tar impacted soils. The base is lined with a layer of stiff clay, with no concrete present and there is evidence that migration of contamination into the underlying Glaciofluvial Deposits has occurred » The base of the later constructed Holder No 2, comprises concrete between 2.30m and 3.00m bgl and a subbase of cobbles of brick between 4.50m and 6.00m therefore migration of dissolved phase contamination into the underlying Glaciofluvial Deposits is unlikely, so long as the completed borehole has been suitably backfilled. » Significant hydrocarbon impacted Made Ground was confirmed at 5.00m bgl in the vicinity of the former Holder No2, purifier house and oxide store and towards the south west. » Hardcore within TP4 was impacted by spent oxide and contained elevated cyanide and a blue hue. » To the east of Holder No1. Strong tar odours were noted between 1.95m and 3.20m bgl. To the west of Holder No1. Solid tar was noted between 0.30m and 2.30m bgl. » It was concluded that there was no significant vapour risk associated with the deep hydrocarbon impacted soils. However, the deep Made Ground in Holder No.1 was confirmed as a source of ground gas with methane at 22.2% and carbon dioxide at 22.9%.

Preliminary conceptual site model based on desk study

<p>Preliminary Geo-environmental Conclusions</p>	<p>Based on historical land uses and its current operational use, the overall risk from land contamination at the site is considered to be moderate for the current development, and moderate for a redeveloped site, but would need to be confirmed by appropriate intrusive investigation, testing and assessment of the results of the investigation.</p> <p>Cheshire East Council state that additional investigation is required to confirm if the site is classified as Contaminated Land under Part 2A of the EPA 1990.</p> <p>The possible pollutant linkages on an un-remediated site determined by desk study and walk-over are summarised below for risk levels of moderate or greater.</p>
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Source(s)	◀ potential Impact on ▶	Receptor(s)
Made Ground, associated with former Gas Holders and Purifier/Oxide Store, including elevated concentrations of metals, metalloids, polycyclic aromatic hydrocarbons (PAH), benzene, toluene, ethylbenzene and xylene (BTEX), complex and free cyanides, thiocyanate, ammonium compounds, sulphate/sulphides, elevated pH, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) (S1) <i>the previous ground investigation completed by LK Associates confirmed the presence of elevated lead, naphthalene, aromatic hydrocarbons within the backfill of Holder No1, as well as hydrocarbon odours and visual evidence of impact in the underlying Glaciofluvial Deposits. Deeper Made Ground in the vicinity of Holder No1 contains evidence of petroleum hydrocarbon impact.</i>		Site end users (R1). Utilities (R2) Groundwater (R3)
Made Ground associated with the former Abattoir potentially included metals, metalloids, PAHs, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC). (S2)		Site end users (R1). Utilities (R2) Groundwater (R3)
Made Ground, potentially containing asbestos fibres and Asbestos Containing Materials from demolition of former gas works and abattoir structures (S3).		Site end users (R1).
Ground gases (carbon dioxide and methane) from organic materials in the Made Ground (S4).		Site end users (R1). Buildings (R2)

Summary of geotechnical conclusions

Preliminary Geotechnical Hazards

The following plausible geotechnical risks are identified.

- » Variable Made Ground - settlement or differential settlement of foundations, floor slabs, roads and infrastructure elements.
- » Brine solution features and voids- the site is in an area where properties have designated prescribed notices of damage and is underlain by wet rock, potential for voids and dissolution features leading to a loss of support of foundations, roads and pavements.
- » Attack of buried concrete by aggressive ground conditions – the development site may contain Made Ground and potentially sulphate bearing soils.
- » Running sands, loose Made Ground and shallow groundwater, leading to difficulty with excavation due to trench instability.
- » Seasonal Groundwater Variations – there is a moderate risk from groundwater flooding and the shallow groundwater within the Glaciofluvial Deposits could be subject to seasonal variations.
- » Attack of buried concrete by aggressive ground conditions – the development site may contain Made Ground and potentially sulphate bearing soils.
- » Shrinkage/swelling of clay – settlement/heave of foundations, especially where located within the influence of trees and vegetation.

- » Existing retaining walls integrity and impact on foundations, floor slabs, roads and infrastructure and construction plant.
- » Potential for obstructions and the risk of instability of excavations with the impact on construction staff, vehicles and plant operators.

Future considerations

Further work

In order to confirm the actual risks to receptors and confirm the ground conditions with respect to potential geotechnical and geo-environmental risks, an appropriate intrusive investigation will need to be undertaken. This investigation will need to:

- » determine the depth and distribution of Made Ground and natural strata across the site;
- » determine the presence of remaining underground structures;
- » target the specific gas works and abattoir features with investigation to adequately characterise the risk posed to receptors;
- » confirm the presence/absence of voids & dissolution features associated with the Northwich Halite Member following agreement of investigation scope with the Brine Board.
- » determine the soil strength/density profile beneath the site;
- » determine the depth/level of groundwater beneath the site;
- » determine the ground gas concentrations beneath the site;
- » determine CBRs to assist with pavement design;
- » assess trench stability, over break potential and 'diggability';
- » allow soil infiltration rate testing;
- » allow sampling for chemical and geotechnical laboratory testing;
- » confirm the vapour risk posed by volatile contamination potentially within soils and groundwater;
- » allow soil classification to allow geotechnical characterisation and determine suitability for reuse of soils within earthworks;
- » obtain information in terms of Aggressive Chemical Environment for Concrete Class (ACEC Class).

Following investigation, assessment will be required to:

- » update the Ground Model;
- » update the Geotechnical Risk Register;
- » provide outline Geotechnical Design recommendations;
- » update the Conceptual Site Model (CSM), including identification of plausible pollution linkages;
- » undertake generic quantitative risk assessment of potential chemical contaminants to establish 'suitability for use' under the current planning regime;
- » discuss potential environmental liabilities associated with land contamination (soil, water and gas); and
- » provide outline mitigation recommendations to ensure the site is 'suitable for use'.

This Executive Summary forms part of Hydrock Consultants Limited report number 33014-HYD-XX-XX-RP-GE-0001 and should not be used as a separate document.

1. Introduction

1.1 Terms of reference

In January 2024, Hydrock Consultants Limited (Hydrock) was commissioned by Knutsford Town Council (the Client) to undertake a Phase 1 Ground Conditions Desk Study at Tatton Street Car Park. The site is located at Tatton Street, Knutsford, WA16 6AG.

The site is currently a car park accessed from Tatton Street to the east. Mature trees are present along some of the site boundaries.

Hydrock understands that the proposed development is to comprise a multi-storey car park. The proposed development layout has yet to be finalised.

The investigation works have been undertaken in accordance with Hydrock's proposal referenced (KNT-HYD-XX-XX-CP-TP-0001) and the Client's instructions to proceed (by email in January 2024).

This study was funded by the UK Government through the Shared Prosperity Fund.

1.2 Objectives

The works have been commissioned to ascertain the viability and costs of the potential development. The objectives of the Phase 1 Ground Conditions Desk Study are to formulate a preliminary Ground Model and an Initial Conceptual Site Model of the site to identify and make a preliminary assessment of any potential geo-environmental and geotechnical risks to the proposed development.

1.3 Scope

The scope of the Phase 1 Desk Study comprises:

- » a field reconnaissance (walkover) to determine the nature of the site and its surroundings including current and former land uses, topography and hydrology;
- » acquisition and review of:
 - » historical Ordnance Survey maps, to identify any; former potentially contaminative uses shown at the site and immediately surrounding it, and an assessment of the associated contamination risks;
 - » a third-party environmental report to identify any; flooding warning areas, local landfills, pollution incidents, abstractions, environmental permits etc. All of which may have had the potential to have environmental impact on the site;
 - » topographical, geological and hydrogeological maps;
 - » British Geological Survey (BGS) archive records;
 - » regional UXB risk maps;
 - » the Coal Authority's Interactive Viewer;
 - » a site-specific Cheshire Brine Compensation Authority 'Cheshire Salt Search'; and
 - » obtain records held by Cheshire East Council (awaiting receipt)
- » development of a preliminary Ground Model representing ground conditions at the site;
- » development of an initial Conceptual Site Model (iCSM), including identification of potential contaminant linkages;
- » a qualitative assessment of any geo-environmental risks identified; and
- » identification of any plausible geotechnical hazards.

1.4 Available information

The following documents, reports etc have been provided to Hydrock by Knutsford Town Council for use in the preparation of this report:

- » Knutsford Town Council. January 2020. Traffic Management and Parking Proposals. From top to bottom street, Knutsford, looking to the past, the present and the future.
- » LK Associates. September 2007. Tatton Street Study Site, Preliminary Risk Assessment and Scoping Investigation. Report Referenced CL1114.

It is understood that the Client defined in Section 1.1 commissioned assignment of the above documents and Hydrock has assumed full reliance can be placed upon their contents. Should this not be the case, Hydrock should be informed at the earliest opportunity.

1.5 Regulatory context and guidance

The geo-environmental section of this report is written in broad accordance with BS 10175:2011+A2:2017, EA LCRM (2023) and the AGS (2006) 'Good Practice Guidelines for Site Investigations'.

The methods used follow a risk-based approach, the first stage of which is a Phase 1 desk study and field reconnaissance, with any potential geo-environmental risks assessed qualitatively. This is done using the 'source-pathway-receptor contaminant linkage' concept to assess risk as introduced in the Environmental Protection Act 1990 (EPA, 1990). Any potential geotechnical risks are also assessed from the Phase 1 desk study and site reconnaissance stage.

Professional judgement is then used to evaluate the findings of the risk assessments and to provide recommendations for the development.

The geo-environmental and geotechnical aspects are discussed in separate sections. Throughout the report the term 'geotechnical' is used to describe aspects relating to the physical nature of the site (such as foundation requirements). The term 'geo-environmental' is used to describe aspects relating to ground-related environmental issues (such as potential contamination). However, it should be appreciated that this is an integrated investigation and these two main aspects are inter-related. Designers should take all aspects of the investigation into account.

Remaining uncertainties and recommendations for further work are listed in Section 5 and Section 6.

2. Desk study (and field reconnaissance)

2.1 Data

A number of desk study sources have been used to assemble the following information. These are presented in Appendix D and include:

- » Third-party environmental report (Groundsure report, reference HYD-SW5-HJV-Z70-22R);
- » Historical Ordnance Survey mapping;
- » BGS Onshore GeoIndex ([GeoIndex - British Geological Survey \(bgs.ac.uk\)](https://www.bgs.ac.uk/geoindex/));
- » BGS borehole records ([Borehole records - British Geological Survey \(bgs.ac.uk\)](https://www.bgs.ac.uk/borehole-records/));
- » BGS maps portal ([BGS maps portal - British Geological Survey](https://www.bgs.ac.uk/maps-portal/));
- » BGS Archive Records;
- » Coal Authority's Interactive Viewer (<http://mapapps2.bgs.ac.uk/coalauthority/home.html>);
- » Cheshire Brine Compensation Authority 'Cheshire Salt Search' (Reference: HYD-O44-O50-ZDP-AF6);
- » DEFRA Magic Map Application <https://magic.defra.gov.uk/magicmap.aspx>;
- » Environment Agency River catchment data ([England | Catchment Data Explorer](https://www.environment-agency.gov.uk/catchment-data-explorer/));
- » Environment Agency flood data (<https://flood-map-for-planning.service.gov.uk/>); and
- » Zetica UXB Risk Maps (<https://zeticauxo.com/downloads-and-resources/risk-maps/>).

2.2 Site referencing

Table 2.1: Site referencing information

Item	Brief Description
Site name	Tatton Street Car Park.
Site address	Tatton St, Knutsford WA16 6AG.
Site location and grid reference	The site is located to the west of Tatton Street in the Northern sector of Knutsford town centre. The National Grid Reference of the approximate centre of the site is 375043E, 378915N. The site is approximately 0.50 Ha in area and measures approximately 125m x 50m.
Site boundaries	The eastern site boundary is Tatton Street. The southern and western boundary is marked by residential properties. The north is bounded by a mixture of residential and office buildings including Caledonian and Victoria House and south west by the Telephone Exchange. There are no listed buildings adjacent to the site.
Sensitive Land Uses and Statutory Boundaries	The Knutsford and Cheshire East Conservation Area is denoted as offsite bordering the south east site boundary. Tatton Mere which is situated 200m east of the site is designated as a Site of Special Scientific Interest and a Conserved Wetland Site, The site lies within the SSSI impact zone therefore consultation will be required to provide evidence that the development will not impact on the SSSI.

Merseyside and Greater Manchester Green Belt Designation 13m east of the site.



Figure 2.1: Site location
(Reproduced with permission from Groundsure)



Figure 2.2: Extract from the Ordnance Survey Map.
(OS licence 100023353).

A site location plan (Hydrock Drawing 33014-HYD-XX-XX-DR-GE-0001) is presented in Appendix A.

2.3 Site description and field reconnaissance survey

A field reconnaissance survey was undertaken on 23rd February to visually identify assess potential geotechnical hazards, contaminant sources for future investigation and identification of possible source-pathway-receptor linkages. The weather during the field reconnaissance survey was sunny with occasional rain showers.

Table 2.2 and selected photographs are presented in Figure 2.3 to Figure 2.6. Additional photographs are presented in Appendix B.

Table 2.2: Site description

Item	Brief Description
Site access	The site was accessed from Tatton Street.
Site area	The site is irregular in shape and has an area of approximately 0.5 ha.
Elevation, topography and any geomorphic features	The site gently slopes down from the north west to the south east from approximately 62m to 59m above Ordnance Datum (OD). Tatton Mere, formed from previous dissolution subsidence features (Serridge and Copper, 2022), is present approximately 200m to the east of the site. A retaining wall is present on the east of the north western car park, approximately 1 m high. The wall retains the soils from the car park onsite and the adjacent Caledonian House Car Park is at the bottom.
Present land use	The site is currently a pay and display car park north of Knutsford town centre. There are no buildings on site, the only structures present are the pay machines and a height restriction barrier at the entrance. The surface

Item	Brief Description
	comprises of asphalt and is generally in good condition and there are a number of manhole chamber present across the site.
Vegetation	Trees are present on the site boundaries, especially on all boundaries of the north western car park and across the southern boundary.

A site features plan (Hydrock Drawing 33014-HYD-XX-XX-DR-GE-0002) are presented in Appendix A.



Figure 2.3: Mature trees on northern boundary.



Figure 2.4: South western section of the car park.



Figure 2.5: Site entrance from Tatton Street.



Figure 2.6: Retaining wall on eastern site boundary. Photograph taken from the Caledonian Car Park.

2.4 Site history

A study of historical Ordnance Survey maps (Appendix D) has been undertaken to identify any former land uses at the site and surrounding areas which may have geotechnical or geo-environmental implications for the proposed development. The key findings are summarised in Table 2.3.

Table 2.3: Site history review

Reference	Key features on site	Key features off-site
OS Map ¹ 1876: 1:2,500 1897: 1:10,560	<p>The site is part of a Knutsford gasworks with a gas holder in the centre with a small rectangular structure south west.</p> <p>There are three unnamed buildings with gardens on the eastern boundary fronting onto Tatton Street. The remainder of the site in the north is open fields.</p>	<p>The wider gas including various adjoined buildings an adjacent circular features (possible water tank) and a second circular features (possible tar well) 40m south west is adjacent on land south west.</p> <p>Tatton Mere is present 200m east.</p> <p>A tannery is shown approximately 120m east of the site.</p> <p>A large pond and associated earthworks is present 140m south west.</p> <p>Residential properties are present in the wider area.</p> <p>An old sand pit is shown approximately 400m to the west.</p>
OS Map 1898: 1:2,500	<p>There is an unnamed rectangular shaped building north west of the gas holder.</p> <p>Part of an unnamed rectangular building encroaches the south west.</p>	<p>Additional unnamed buildings are added to the wider gas works to the south west.</p> <p>Continued residential development to the south, west and east.</p>
OS Map 1909: 1:2,500	<p>A second gas holder is constructed in the north west of the site.</p>	<p>Smaller buildings appear to slightly reconfigure on the wider gas works site.</p> <p>The tannery is now marked as a laundry.</p>
OS Map 1965-1966: 1:2,500 1964 – 1969: 1:10,560	<p>In 1953 the gas holder in the centre is longer recorded and assumed removed down to concrete slab level; the guided frame may have remained.</p> <p>By 1950 the gas works ceased productions the north west gas holder and unnamed rectangular building to the south east remains.</p>	<p>Offsite to the south west the majority of the former gas works infrastructure is no longer recorded and demolished with Cheshire Council Buildings constructed.</p> <p>A water tower is marked to the south west of the site, with mains feeding from Albert Street.</p> <p>Caledonian house and a laundry building is shown to the north east of the site alongside residential developments.</p> <p>Tatton Park (National Trust) is shown approximately 100m north east of the site.</p>
OS Map 1974 - 1977: 1:2,500	<p>The site is now marked as a car park with a cluster of structures in the south east of the site. The rectangular building is demolished. The gas holder in the</p>	<p>An electricity substation is now shown to the north east of the site associated with Caledonian House.</p> <p>The telephone exchange is shown to the south of the site.</p>

¹ Ordnance Survey Historical Map Information provided by Groundsure.

Reference	Key features on site	Key features off-site
	north west is no longer recorded and above ground infrastructure removed.	
OS Map 1985: 1:2,500	The buildings in the south eastern corner of the site are marked as an abattoir.	Any remaining above ground structures associated with wider gas works are demolished. The council building, which is recorded as a depot. A building north of Caledonian House, 30m east of the site is recorded as a depot.
OS Map 1991 - 1993: 1:2,500	No significant changes.	No significant changes.
OS Map 2003: 1:2,500	No significant changes.	No significant changes.
Google Earth© Imagery 2003-2023 ² .	No structures are shown on site. Entire site is shown to be a car park. Trees are present on the north, west and southern boundaries.	No significant changes.

2.5 National Grid Archive historical plans

Historical plans of the former Knutsford gasworks have been obtained from the National Grid Archives. The plans from 1913 depict the site layout as shown in Figure 2.7 and Figure 2.8 from 1913 & 1957.

The plans show the older column guided Gas Holder No.1 (with a volume of 46,000 cubic feet) in the centre and column guided Gas Holder No.2 (with a volume of 120,000 cubic feet) in the north west. The purifier and oxide store are situated north west of holder No.1. Inlets/outlets and high/low pressure gas main infrastructure are present south of holder No.2 and west of the purifiers. The canteen/former station meter house encroaches the south west. There is a gas governor and syphon pit south west of Gas Holder No.1.

As shown by the provided plans, the wider Knutsford gasworks infrastructure to the south west includes the retort houses (at approx. 15m), coal store (at approx. 30m), tar/liquor wells (at approx. 40m), exhausters (at approx. 35m), scrubbers (at approx. 35m), tar boilers (at approx. 35m) and workshop (adjacent/encroaching). Figure 2.8 records holder No.1 as infilled and holder No.2 as partially infilled, the infill is unknown.

The partial infilling of Gas Holder No.2 would suggest that there may be below ground infrastructure associated with holder remaining, based on the volume and size of the holder. It is possible that the below ground holder structure may have been filled, but below the concrete holder base the water filled void above the dumping may have not been infilled.

The historical site features are shown on Hydrock Drawing 33014-HYD-XX-XX-DR-GE-0004 presented in Appendix A.

² ©Maxar Technologies, image date: 16/4/2003; ©Airbus, image date: 08/06/2023.



Figure 2.7: 1913 National Grid plan



Figure 2.8: 1957 National Grid plan (Approximate Red Line Boundary Shown)

2.6 Geology

The geology of the site area is shown on the 1:10,000 British Geological Survey (BGS) map extract reproduced as part of the Groundsure report and is summarised below:

Table 2.4: Geology

Ref. for Figures	Location	Stratigraphic Name	Description
Superficial Deposits (Figure 2.9)			
1	On site	Glaciofluvial Deposits	Sand and gravel
3	North eastern boundary	Glacial Till	Clay with sands and gravel.
5	180m east	Alluvium	Clay, silt, sand and gravel.
Solid Geology (Figure 2.10)			
1	On site.	Northwich Halite Member	Halite with partings of mudstone.

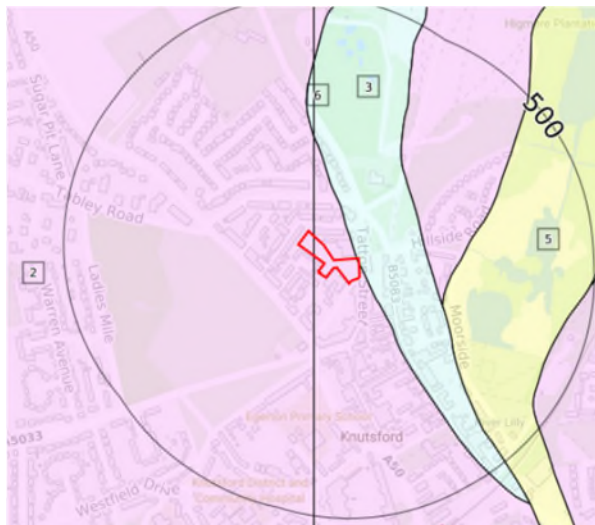


Figure 2.9: Superficial deposits.

(Reproduced with permission from Groundsure)

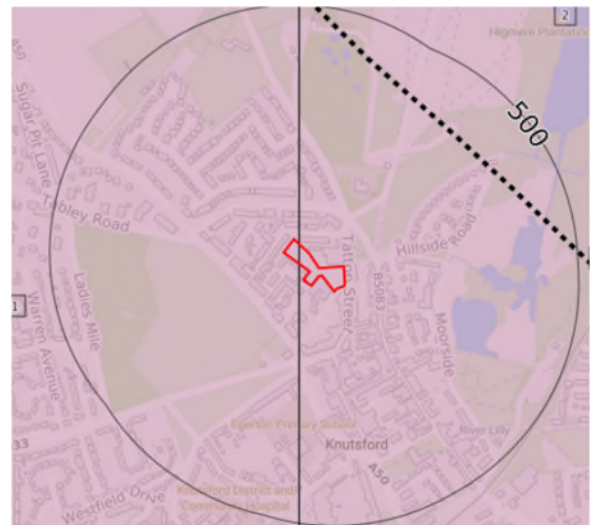


Figure 2.10: Solid geology.

(Reproduced with permission from Groundsure)

A fault, trending approximately north west - south east, with a downthrow to the north east, is located approximately 370m to the north east of the site.

BGS mapping also indicates that beneath the site there is a buried channel feature filled with superficial deposits of between 20-30m in depth. Likely to include Glaciofluvial Deposits underlain by Glacial Till

A number of borehole logs from the BGS archive have been reviewed. Selected records are summarised below:

- » SJ77NE3/A, located on site (375029E, 378905N), drilled in 1934 to a depth of 7.62m and recorded:
 - » Made Ground between ground level and 0.30m below ground level (bgl);
 - » Yellow loamy sand between 0.30m and 1.40m bgl (probable Glaciofluvial deposits);
 - » Yellow sand between 1.40m and 1.62m bgl (probable Glaciofluvial deposits);
 - » Red sand between 1.62m and 1.92m bgl (probable Glaciofluvial deposits);
 - » Loamy red sand between 1.92m and 4.88m bgl (probable Glaciofluvial deposits); and
 - » Coarse sand and gravel between 4.88m and 7.62m bgl (probable Glaciofluvial deposits).
- » SJ77NE3/B, located on site (375029E, 378905N), drilled to a depth of 7.62m and recorded:
 - » Coarse sand and gravel between ground level and 7.62m bgl (probable Glaciofluvial deposits).
- » SJ77NE3/A, located 50m south east (375110E, 378830N), drilled to a depth of 8.00m and recorded:
 - » Made Ground between ground level and 0.90m bgl;
 - » Loose SAND from 0.90m to 1.30m bgl (probable Glaciofluvial Deposits);
 - » Soft to firm brown sandy CLAY from 1.30m to 2.60m bgl (probable Glaciofluvial Deposits);
 - » Firm to stiff brown sandy CLAY from 2.60m to 3.50m bgl (probable Glaciofluvial Deposits);
 - » Dense brown silty SAND 3.50m to 5.50m bgl (probable Glaciofluvial Deposits); and
 - » Medium dense brown SAND from 5.50m to 8.00m bgl (probable Glaciofluvial Deposits).
 - » No Groundwater Encountered.

2.7 Hydrogeology

2.7.1 Aquifer designations

Based on the inferred geological sequence presented in Section 2 and the Environment Agency's interactive aquifer designation map, the aquifer system presented in Table 2.5 applies. Additional information on the hydraulic characteristics of the geological units has been abstracted from Allen et al (1997) and Jones et al (2000).

Table 2.5: Aquifer system

Stratum	Aquifer Designation	Comments
Made Ground (Imported Fill)	Unclassified/unproductive	Artificial ground not included in the classification system. Likely to be moderate to high porosity because of unconsolidated nature, but permeability is likely to be constrained to low, or low to moderate because of poor sorting and clay content.
Superficial Deposits		
Glaciofluvial deposits	Secondary A Aquifer	Intergranular permeability. Dominated by moderate to high permeability layers of sand and gravel. Within this unit horizontal permeability may be greater than vertical permeability as the

		<p>presence of clay bands restricts the vertical movement of groundwater.</p> <p>Dissolved or leachable contaminants have the potential to migrate horizontally or vertically through the permeable layers of sand or gravel.</p>
Solid Geology		
Northwich Halite Member	Unproductive	<p>Dominated by low permeability and low porosity mudstone. Potentially faulted and fractured, but is generally considered impermeable.</p> <p>There is potential moderate to high permeability along bands of halite, which will have a moderate to high porosity.</p>

2.7.2 Groundwater abstraction

There are no active licensed groundwater abstractions within 1000m of the site.

2.7.3 Groundwater source protection zones and groundwater vulnerability

The site is not within a groundwater Source Protection Zone (SPZ).

The superficial deposits constitute a Secondary A aquifer with a high vulnerability classification. The bedrock is classified as unproductive strata and therefore has a negligible risk.

2.7.4 Groundwater levels, recharge, and flow

Shallow groundwater is likely to be present within the Glaciofluvial deposits. There is potential for discontinuous/local perched groundwater within the Made Ground.

The shallow groundwater will likely flow east towards the River Lily 190m east which present on Tatton Mere. However, the shallow groundwater is unlikely to be in direct hydraulic continuity with the River Lilly, the presence of the low permeability Glacial Till to the east will act as a confining unit.

As the site is covered by hardstanding and underlain by Made Ground, recharge the shallow groundwater is unlikely to occur onsite. Recharge is more likely to occur on the Heath a large area of landscaping/public open space 100m west.

The potential for the presence of deep foundations associated with the gasholders may be locally impeding shallow groundwater flow.

Due to the high permeability of the sand and gravel in the Glaciofluvial Deposits, dissolved or leachable contamination could migrate laterally and vertically. The lateral migration of contamination could be restricted by low permeability layers of clays that may be present within the Glaciofluvial Deposits, similarly to those present in historic borehole SJ77NE3/A.

2.7.5 Groundwater quality

The groundwater body beneath the site (Weaver and Dane Quaternary Sand and Gravel Aquifers) is currently (2019 Cycle 3) classified under the Water Framework Directive as 'poor'.

The water body is currently given a 'poor' status due to 'chemical dependant surface water body', 'Chemical GWDTes test' and 'general chemical test' conditions. The objective is for all chemical status' to be 'good' by 2027.

2.7.6 Groundwater flooding

The environmental data report indicates a moderate risk of groundwater flooding. Seasonal variation in groundwater depth, and the permeable nature of the Glaciofluvial Deposits could lead to temporally higher groundwater table.

2.8 Hydrology

2.8.1 Surface water system and drainage

The closest surface water feature is the River Lily, approximately 190m east of the site. The River Lily flows north to Tatton Mere.

2.8.2 Surface water abstractions and discharges

There are no the active licensed surface water abstractions within 1km of the site.

There are 2 active licensed surface water discharges within 1km of the site. They are listed in Table 2.6.

Table 2.6: Surface water discharges

Location Relative to Site	Details
290m south east	Sewage discharges to Moor Pool
410m south east	Sewage discharges to Ditton Brook

2.8.3 Surface water quality

Reference to the Environment Agency web site shows the site is located within the catchment known as the North West River Basin District. The specific river water body being the Birkin Brook – Source to Mobberley. The current (2022 cycle 3) overall status under the Water Framework Directive is described as 'poor'.

The reason for the water body currently having a 'poor' status is due to Macrophytes Sub Element and Phosphate levels. The objective is for phosphate levels to be 'good' by 2027.

2.8.4 Surface water flooding

The desk study information indicates the proposed development is in Flood Zone 1 with a low probability of flooding from rivers or the sea.

No further consideration of flood risk is undertaken in this report. Specialist flood risk advice should be sought with regard to drainage and flooding.

2.9 Mining and mineral extraction

The site is not within a Coal Mining Reporting area as defined by the Coal Authority.

Historical surface mineral extraction of sand is recorded on the historical mapping and the environmental report. The Heath Sand Pit is located approximately 380m to the west of the site and is now within an area of woodland.

As shown in Figure 2.11 (site location yellow star) there are no salt subsidence features shown below the site, Tatton Mere 200m east as mentioned in Section 2.2. is classed as a salt subsidence feature. There are no salt springs or salt & alkali works recorded in the vicinity of the site which would have excessively pumped brine from underground.

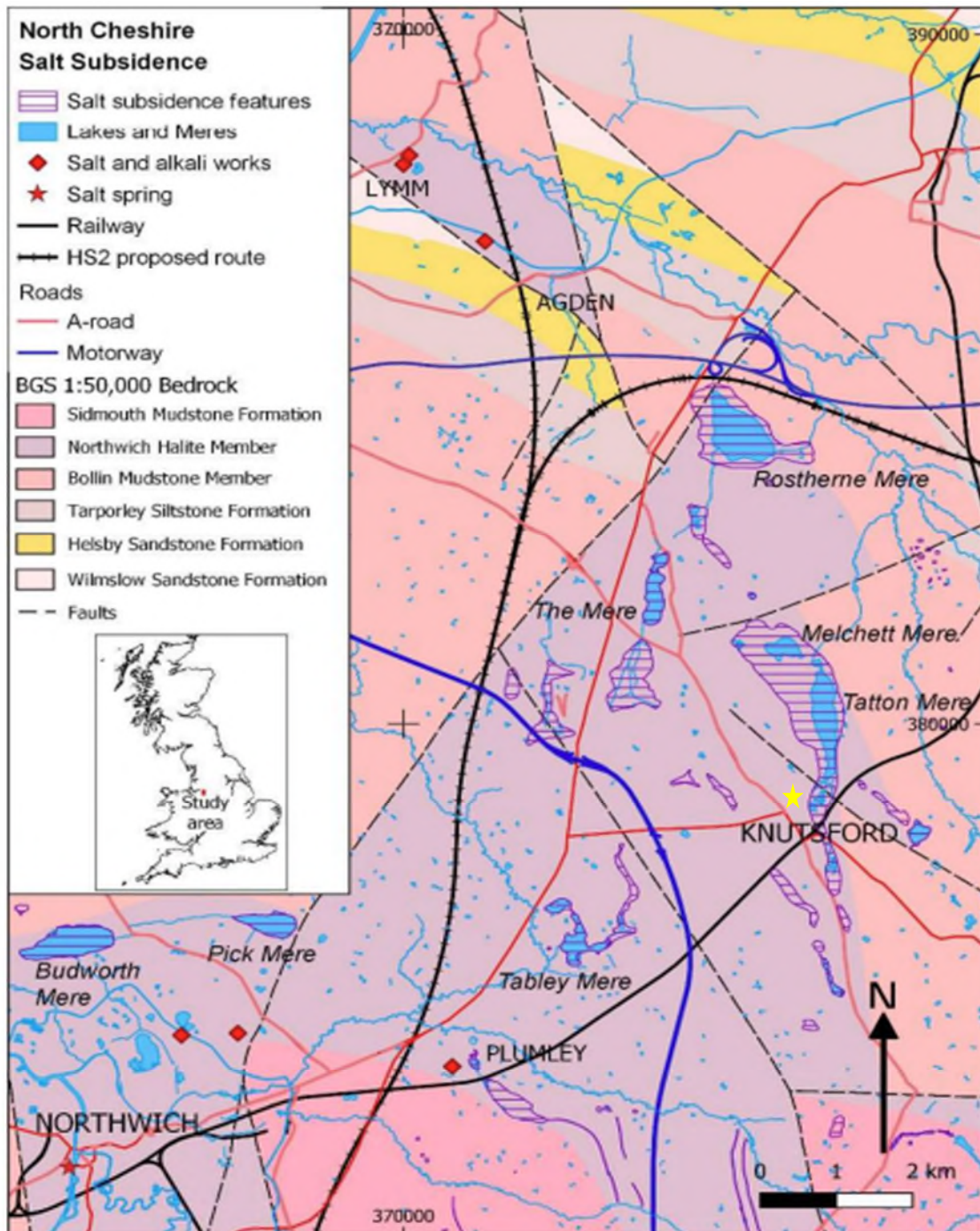


Figure 1. North Cheshire, location, geology, subsidence features and meres BGS © UKRI. Contains British Geological Survey materials ©BGS UKRI 2022; Contains OS data © Crown copyright 2022.

Figure 2.11: Extract from the Serridge and Cooper 2022 (Quarterly Journal of Engineering Geology and Hydrogeology).

2.9.1.1 Cheshire salt search

As the site is within an area defined by the Cheshire Brine Subsidence Board as a Compensation District a Cheshire Salt Search has been obtained from Groundsure, who administer the search on behalf of the Cheshire Brine Subsidence Compensation Board. The board assesses and administers compensation under The Cheshire Brine Pumping (Compensation for Subsidence) Act 1952. The search reports the following:

- » The site is located within the compensation district as defined by the 1952 Act.
- » The site is located within a consultation area as prescribed by the Cheshire Brine Subsidence Compensation Board under the provisions of section 38(1) of the 1952 Act.
- » There have been no prescribed notices of damage filed in respect to the site since 8th January 1959.
 - » There are 5 buildings to the north west of the site within 20m which have prescribed notices of damage as shown in Figure 2.12.
 - » The site was of industrial use with most structures demolished by 1959 when Prescribed Damages of Notice were filed, there is unlikely to be prescribed notices of damage specific to site.



Figure 2.12: Prescribed Notice of Damage

- » There are no historic brine wells/ shifts located within 20m of the property.

- » There are not any areas, lines or point of weakness relating to historic brine pumping or natural dissolution within 50m of the site.
- » The site does not lie within a DM32 planning policy area which places conditions on the development within the former mined areas.
- » There are not any current or proposed uncontrolled brine pumping operations within 3km of the site.
- » There are not any planning consents for brine extraction by controlled methods within 200m of the site.
- » The site is not within 90m of an area that could be affected by historical (abandoned) rock salt underground mining.
- » The site is not within the GS7 planning policy boundary which requires planning applications to have regard to potentially unstable rock salt mine workings. Note this area covers an area introduced by Vale Royal Borough Council, this council was abolished and the area now sits within the Cheshire West and Chester Council area. The policy is in the process of being replaced.
- » There is not a planning consent for rock salt extraction by underground mining within 120m of the site.

2.9.1.2 *Impacts of proposed development in areas of potential brine dissolution*

Construction activities can increase the risk of the collapse of underground cavities via a number of activities:

- » By increasing the loading over any voids leading to a greater chance of collapse.
- » By transferring loads through strata towards voids by utilising piles.
- » By removing material via excavation can reduce the thickness of the deposits over any voids reducing the material bridging them.
- » Works could relieve ground water pressures, through dewatering, within brine runs. The water could be providing support to the walls of the runs.
- » The drainage strategy could introduce fresh water into the ground which could promote salt dissolution.

2.9.1.3 *Conclusion*

Given the proximity of the site to the properties with prescribed notices of damage and underlying wet rockhead, the scope of the ground investigation should be discussed and agreed with the Brine Board. Allowance should be made for deep boreholes including rotary coring to investigate the rockhead. The top 'wet rock' could be present between 20-30m bgl given the site is underlain by a buried valley.

2.10 Natural/Anthropogenic ground instability

The environmental report indicates a very low to negligible risk from shrink well clays, compressible deposits, collapsible deposits and landslides. However, due to the presence of Glaciofluvial deposits at the site and unknown groundwater levels within the superfluentials there is a risk of running sands at the site.

Trees and hedges are present along the site boundaries and the shallow cohesive soils of the Glaciofluvial Deposits may be subject to shrink or swell following the removal or planting of trees.

The environmental report indicates there is a very significant risk from soluble rocks with a high possibility of localised subsidence or dissolution-related degradation of the bedrock. There is potential for voids to migrate to the surface forming sinkholes associated with historic brine

pumping. As part of the ground investigation the presence of absence of dissolution features should be confirmed and scope of investigation agreed with the Brine Board.

The environmental report highlights an area to the east of the site included within the BGS karst database and associated with Tatton Mere. Subsidence related to dissolution is a risk to the site as it is underlain by the Northwich Halite Member.

Variable heterogeneous Made Ground deposits associated with the former gas works on site present a geotechnical hazard. Composition and depth of Made Ground should be determined as part of an intrusive investigation.

The Made Ground may contain elevated sulphates, during future ground investigation the sulphate concentrations in the Made Ground should be established to correctly classify the below ground concrete.

Obstructions are may be present associated with below ground infrastructure and pipework remaining from the former Gas Holders/gas works infrastructure.

2.11 Waste management

There are no current or historical waste management sites recorded within 250m of the site.

There are 4 sites with waste exemptions recorded within 250m of the site, as listed in Table 2.7

Table 2.7: Waste management sites

Site Name and Location	Details
Windsor way, 50-80m south west	Treating waste – not on a farm Sorting and de-naturing of controlled drugs for disposal
Tatton street, 100 – 120m south	Treating waste – not on a farm (non-agricultural waste only) Sorting and de-naturing of controlled drugs for disposal
Oakwood lane, 160 – 170m south	Treating waste – not on a farm Sorting and de-naturing of controlled drugs for disposal
Princess street 170 – 180m south	Treating waste – not on a farm (non-agricultural waste only) Sorting and de-naturing of controlled drugs for disposal

2.12 Regulatory Information

Information in the Groundsure Report (Appendix D), relating to various regulatory controls has been reviewed, with a summary presented below in Table 2.8.

Table 2.8: Regulatory information within 500m of the site

Regulatory Data	Distance from Site	Details	Potential Risk	Comment
Local Authority Pollution Prevention and Controls	175m south	Part B permit Dry cleaning	No	Due to its proximity to the site.
	455m south	Part B permit Dry cleaning	No	Due to small volume of waste

Regulatory Data	Distance from Site	Details	Potential Risk	Comment
				and distance from the site
Pollution Incidents	310m south east	January 2010, pollutant not identified, Category 2 - significant impact (water), Category 4 - no impact (land and air)	No	Due to its distance from the site and it being down gradient.
	340m south east	January 2004, crude sewage, Category 1 - major impact (water), Category 4 - no impact (land and air)	No	Due to its distance from the site and it being down gradient.
	360m south east	November 2006, crude sewage, Category 2 - significant impact (water), Category 3 - minor (land), Category 4 - no impact (air).	No	Due to its distance from the site and it being down gradient.
	360m south east	October 2004, crude sewage, Category 2 - significant impact (water), Category 4 - no impact (land and air).	No	Due to its distance from the site and it being down gradient.
	370m east	December 2002, natural ochre, Category 3 - minor (water), Category 4 - no impact (land and air).	No	Due to its distance from the site and the Category 3/4 classification of the incident.
	460m south east	May 2002, diesel, Category 3 - minor (water), Category 4 - no impact (land and air).	No	Due to its distance from the site and the Category 3/4 classification of the incident.
Trade Directory Entries	20m east	Electrical equipment repair and servicing	No	Area likely underlain by low permeability clays restricting migration of contamination.
	50m north east	Stone quarrying and preparation.	No	Due to the small volumes of potential contaminants.

Regulatory Data	Distance from Site	Details	Potential Risk	Comment
	90m east	Rubber, silicones and plastics.	No	Due to the small volumes of potential contaminants and its distance from the site.
	100m south east	Clothing, components and accessories.		
	100m south east	Construction services.	No	
	110m south	Electricity sub station		
	140m north west	Electricity sub station		
	200m south	Electricity sub station		
	230m south east	Vehicle parts and accessories		
	230m south east	Construction services		
Fuel Station Entries	475m south	Open Petrol station	No	Due to distance from the site
Control of major accident hazards sites (COMAH)	N/A	No entries on COMAH sites were recorded within 500m of the site.	-	-
Registered radioactive substances	N/A	No entries on registered radioactive substances were recorded within 500m of the site.	No	-
Notification of installations handling hazardous substances	N/A	No entries on notification of installations handling hazardous substances were recorded within 500m of the site.	No	-

2.13 Consultation

Cheshire East Council were contacted on 12th February 2024 requesting information pertaining to the site. A formal response was received from the land quality team enforcement officer on 12th of March 2024 presented in Appendix D and stated:

- » There are no entries for Part 2A for the subject site and surrounding area, however it is noted that part of the site is a former gas works and further inspection is required under the Part 2A Environmental Protection Act 1990 legislation;

- » The site has been assigned a priority ranking of 76 (out of 4552 sites) however this is list dynamic and subject to change. There are no timeframes on when further inspections would be carried out.

Planning History:

- » The site was redeveloped into a car park in 1989 and was not subject to investigation and remediation;
- » A land contamination report was prepared for the subject site by LK Associated in September 2007 referenced CL114-02;
- » The report concluded that there was no significant pollutant linkage between Elizabeth Gaskell Court Site and the car park;
- » The risk to controlled waters was not assessed within the report, the report was primarily concerned with human health and visual concerns; and
- » There are no registered landfill sites within 250m of the site boundary.
- » As mentioned above the site remains on the councils list of sites prioritised for inspection under Part2A of the Environmental Protection Act 1990.

2.14 Previous Ground Investigations

2.14.1 *Environmental Advisory Unit/Exploration Associates (1988)*

Within the LK Associates Ground Investigation Report (CL114-02) reference is made to an earlier ground investigation undertaken on the site in 1988 by EAU which is summarised below.

Ground Investigation Scope

Exploration Associates on behalf of EAU undertook a ground investigation which included boreholes and trial pits on the subject site. The investigation locations, shown in Figure 2.13, included five trial pits to a maximum depth of 3.2m and BH5 in Holder No.2 completed to 1.00m bgl and BH6 in Holder No1 completed to 10.00m bgl.

Ground Conditions

The surface covering during the ground investigation comprised concrete hardstanding. The backfill within Holder No1. comprised clayey/silty SAND with notable tar odours at 5.50m and 6.80m bgl. The base of the Made Ground was noted at 7.80m bgl., between 6.80m and 7.50m bgl a firm to stiff sandy gravelly CLAY was encountered underlain by natural medium dense gravelly SAND to 10.00m bgl. The natural SAND contained a tar odour between 7.50m and 8.50m bgl. There was no evidence of concrete base suggesting the dumping was lined with CLAY. Water within the Holder is present at 3.00m bgl.

The backfill within Holder No2, comprised a clayey SAND, sandy CLAY (notable black staining) with man-made constituents including brick, concrete, timber and ash. No water was encountered within the holder. Between 2.30m and 3.00m bgl concrete was encountered underlain by cobbles of brick, in turn underlain by medium dense gravelly SAND with no visual or olfactory odours to 10.00m bgl. Unlike Holder No1. the later constructed Holder No2. Appears to have had a competent base, given the boreholes encountered a concrete obstruction beneath the Made Ground which was then underlain by brick cobbles with no standing water within the holder.

Evidence of Contamination

Other notable findings included solid tar within TP5 between 0.30m and 2.30m bgl underlain directly by natural sand. Within TP4 a hardcore at 0.75m was impacted by spent oxide and contained elevated cyanide. Within TP7 Made Ground was found to contain a strong tar odour between 1.95m and 3.20m bgl.

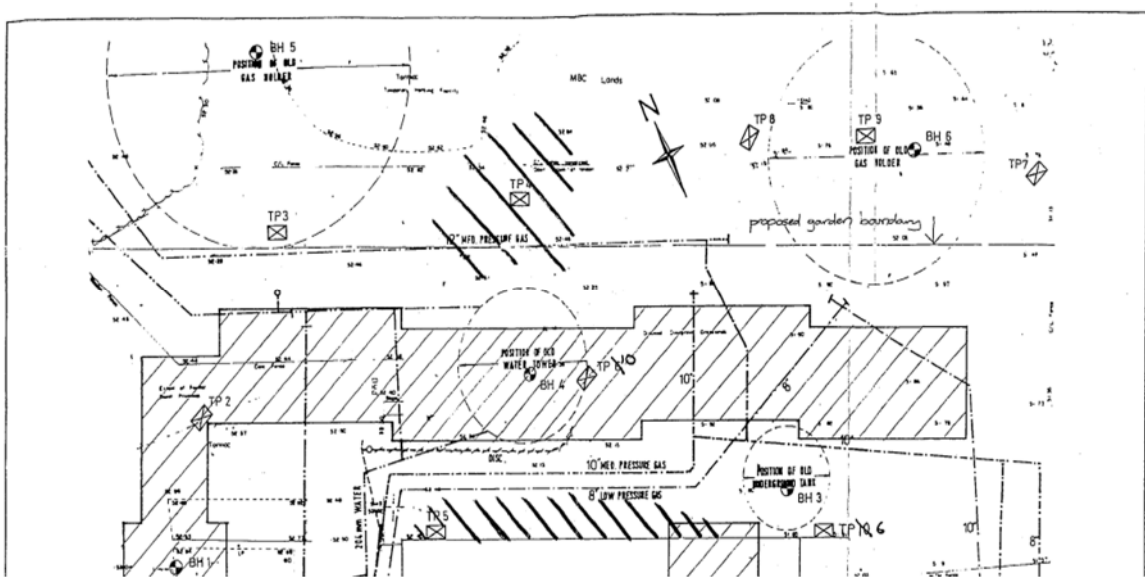


Figure 2.13: Extract from Exploration Associates Exploratory Hole Location Plan

2.14.2 LK Associates Ground Investigation (CL114-02)

Ground Investigation Scope

LK Associates completed a ground investigation on the subject site as shown in Figure 2.14, this included six window sample boreholes to depths between 4.40m and 7.00m bgl. Features including the Gas Holders and Purifier Shed were targeted.

Ground Conditions

Natural gravelly sand was encountered in WS102 at 1.20m bgl, all other locations terminated in Made Ground. The Made Ground comprised medium to coarse sand or sandy clay with gravel of ash, brick, clinker and fowl lime with evidence of decaying matter and organic pockets. Hydrocarbon/tar odours were noted in WS101 at 0.85 and 6.00m, WS103 at 5.00m, WS104 at 5.00m, WS105 at 0.5m and WS106 at 2.60m bgl.

Evidence of Contamination

Contamination testing was generally carried out on deeper samples at depths between 5.00m and 6.40m bgl. Within Holder No1 at 6.40m bgl significantly elevated lead and naphthalene were present, in addition, Aromatic Hydrocarbon fraction EC21 to EC40 was present at 9,700mg/kg.

Within WS106 at 5.00m elevated PAHs were encountered. The Made Ground also contained significant elevated Aromatic Hydrocarbon fraction EC12 to EC16 at 870mg/kg which is considered to be of moderate mobility in groundwater. Trimethylbenzene and 1,2,4-Trimethylbenzene were also present within the Made Ground.

It was concluded that the area of the gas holder No1. and water tank comprise significant hydrocarbon impacted Made Ground at depth.

As part of the ground investigation vapour monitoring confirmed no significant risk from the hydrocarbons impacted soils at depth. Utilising PID/FID instrumentation it was confirmed that elevated methane at 22.2% in WS101 was not being driven by degrading hydrocarbons. Carbon dioxide was also elevated at 22.2% in WS101 and generally at concentrations between 4% and 8.5% within other boreholes with low flows measured.

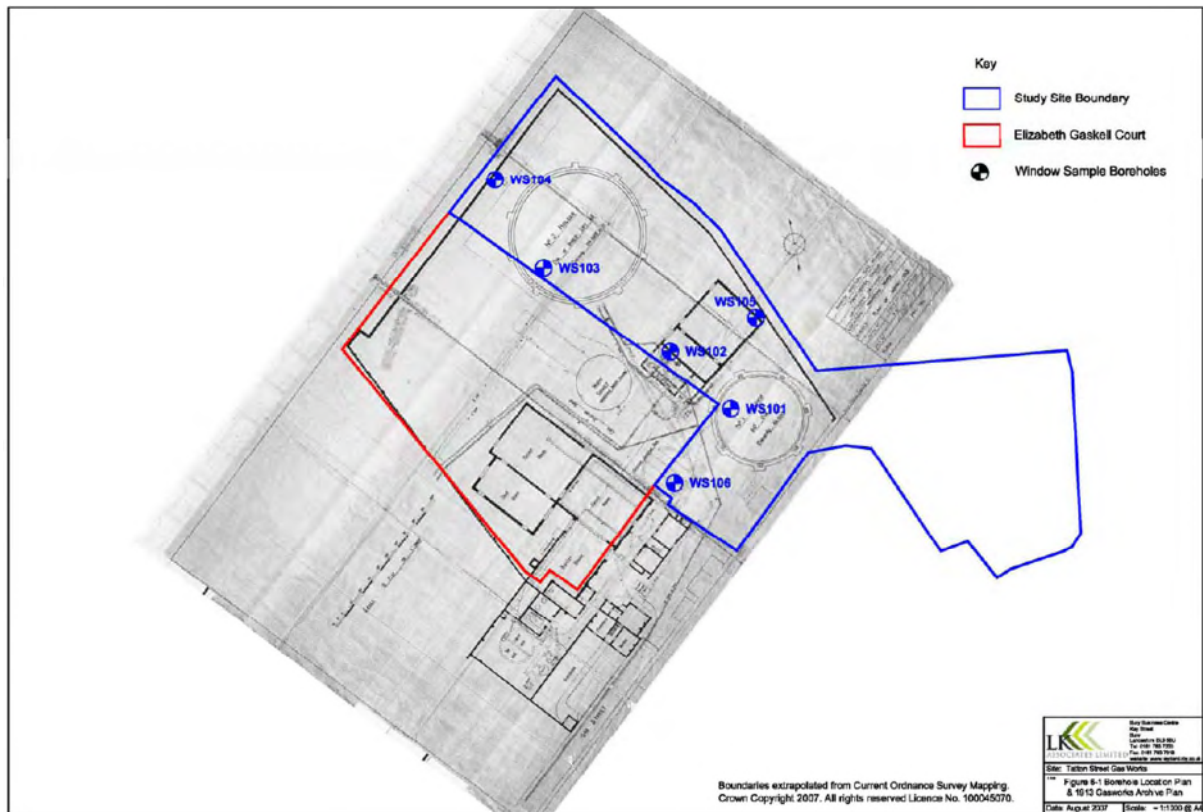


Figure 2.14: LK Associates Exploratory Hole Location Plan

2.15 Natural soil chemistry

Information contained within the environmental report (Appendix D) gives indicative (estimated) concentration values for the natural soils at the site for a selection of Contaminants of Potential Concern (CoPC). These have been reproduced in Table 2.9.

As shown in Table 2.9 the concentrations of natural Contaminants of Potential Concern (CoPC) are below the generic assessment criteria for a commercial end use, therefore no further consideration is required.

Table 2.9: Natural soil chemistry

Element	Arsenic	Cadmium	Chromium	Lead	Nickel
Concentration (mg/kg)	15	1.8	60 - 90	100	15

2.16 Radon

The radon risk is reported in the environmental report which indicates that the site is not in a Radon Affected Area and no radon protection measures are required.

2.17 Unexploded ordnance (UXO)

In general accordance with CIRIA Report C681 (Stone et al 2009) a non-specialist UXO screening exercise has been undertaken for the purposes of ground investigation and is presented in Table 2.10.

Table 2.10: Non-specialist UXO screening (for the purposes of ground investigation)

Data	Comment	Further Assessment Required
Site History	There is no indication of former military use from the desk study.	No
Post War Development	There is no evidence of bomb damage on post war mapping.	No
Geology Type	The ground conditions comprise thick Glaciofluvial deposits (likely medium dense to dense in nature) over the Northwich Halite Member. It is unlikely UXO would remain undetected.	No
Surface Cover during WWII	The surface cover during WWII comprised a significant proportion of hardstanding, concrete and buildings. The gas works was still currently active during WWII and likely regularly visited. It is unlikely UXO would remain undetected.	No
Indicator of Aerial Delivered UXO	Screening against the regional bomb risk map (Cheshire) Appendix D indicates the site to be in an area where the bomb risk is low.	No

The non-specialist UXO screening exercise has indicated no further assessment is required with regard to UXO in relation to ground investigation. Further assessment may be considered prudent for construction activities.

3. Initial conceptual site model

3.1 Introduction

The initial Conceptual Site Model (CSM) incorporates evidence from the site walkover, the Desk Study and previous investigations carried out at the site. The formulation of an initial CSM is a key component of the LCRM methodology, and incorporates: a ground model of the site physical conditions; and an exposure model of the possible contaminant linkages. It forms the basis for Generic Quantitative Risk Assessment (GQRA) in accordance with current guidelines.

3.2 Ground model

The preliminary ground model presented in Section 2 provides an understanding of the ground conditions and is the basis for preparing the preliminary geotechnical hazard assessment (Section 3.3) and the preliminary geo-environmental exposure model (Section 3.4).

3.3 Geotechnical hazard identification

3.3.1 Context

The preliminary geotechnical hazard identification has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622.

The following section sets out the identified geotechnical hazards and the development elements potentially affected (see Table E.1 in Appendix E for further information).

3.3.2 *Plausible geotechnical hazards*

Plausible geotechnical hazards identified at the site are:

- » Uncontrolled Made Ground (variable strength and compressibility).
- » Soft / loose compressible ground (low strength and high settlement potential).
- » Variable lateral and vertical changes in ground conditions.
- » Attack of buried concrete by aggressive ground conditions.
- » Obstructions deep and shallow associated with gas holders and former structures.
- » The existing retaining wall and its impacts on the development and surrounding sites.
- » Shallow groundwater.
- » Changing groundwater conditions.
- » Running sands and / or loose Made Ground, leading to difficulty with excavation and collapse of side walls.
- » Dissolution (associated with 'wet rock head') and past brine extraction.

3.3.3 *Potential development elements affected*

Development elements potentially affected by geotechnical hazards are:

- » Buildings – foundations.
- » Buildings – floor Slabs
- » Roads and pavements.
- » Services.
- » Construction staff, vehicles and plant operators.
- » Concrete below ground.

Health and safety risks to site Contractors and maintenance workers have not been assessed during these works and will need to be considered separately during design.

3.4 Geo-environmental exposure model

3.4.1 Context

The preliminary exposure model is used to identify geo-environmental hazards and to establish potential contaminant linkages, based on the source-pathway-receptor (SPR) approach.

A viable contaminant linkage requires all the components of an SPR to be present. If only one or two are present, there is no linkage and no further assessment is required.

3.4.2 Potential contaminants

For the purpose of this assessment the potential contaminants have been separated according to whether they are likely to have originated from an on-site or off-site source.

3.4.2.1 Potential on-site sources of contamination

- » Made Ground, associated with former Gas Holders and Purifier/Oxide Store, including elevated concentrations of metals, metalloids, polycyclic aromatic hydrocarbons (PAH), benzene, toluene, ethylbenzene and xylene (BTEX), complex and free cyanides, thiocyanate, ammonium compounds, sulphate/sulphides, elevated pH, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) (S1)- *the previous ground investigation completed by LK Associates confirmed the presence of elevated lead, naphthalene and aromatic hydrocarbons within the backfill of Holder No1, as well as hydrocarbon odours and visual evidence of impact in the underlying Glaciofluvial Deposits. Deeper Made Ground in the vicinity of Holder No1 contains evidence of petroleum hydrocarbon impact.*
- » Made Ground associated with the former Abattoir potentially included metals, metalloids, PAHs, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC). *Based on the time of closure pathogens are likely to have diminished (S2)*
- » Made Ground, potentially containing asbestos fibres and Asbestos Containing Materials from demolition of former gas works and abattoir structures (S3).
- » Ground gases (carbon dioxide and methane) from organic materials in the Made Ground (S4).
- » Vapours from potential VOCs, BTEX and petroleum hydrocarbons associated with the former Gas Works and Abattoir (S5).

3.4.2.2 Potential off-site sources of contamination

- » PCBs and oils from the electricity substation to the north of the site (S6).
- » Migration of contaminants from the offsite wider Knutsford Gas Works, associated with the Tar and Liquor Wells possibly including elevated concentrations of benzene, toluene, ethylbenzene and xylene (BTEX), complex and free cyanides, thiocyanate, ammonium compounds, sulphate/sulphides, elevated pH, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) (S7)

3.4.3 Potential receptors

The following potential receptors in relation to the proposed land use have been identified.

- » People (neighbours, site end users) (R1).
- » Development end use (buildings and utilities) (R2).
- » Groundwater: Secondary A aquifer status of the Glaciofluvial deposits (R3).

Limited landscaping is likely proposed on the site, however given the limited Topsoil onsite, there will be a requirement to import suitable Topsoil for landscaped areas.

3.4.4 Potential pathways

The following potential pathways have been identified.

- » Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).
- » Direct contact with substances deleterious to water pipelines (P2).
- » Methane and carbon dioxide ingress via permeable soils and/or construction gaps (P3).
- » VOC and petroleum hydrocarbon vapour ingress via permeable soils and/or construction gaps (P4).
- » Migration of contaminant via leachate or dissolved phase migration through the unsaturated zone into the Glaciofluvial deposits (P5).

Health and safety risks to site development contractors and maintenance workers have not been assessed as part of this study and will need to be considered separately. The above sources, pathways and receptors have been considered as part of the Preliminary Risk Assessment in accordance with LCRM (2023), are considered to be plausible in the context of this site and have been carried forward for assessment. An assessment of the Source – Pathway – Receptor linkages is undertaken following the assessment and is presented in Appendix F (Table F.1).

The Preliminary Conceptual Site Model are shown on Hydrock Drawing 33014-HYD-XX-XX-DR-GE-0003 presented in Appendix A.

3.4.5 Potential implications of climate change

Climate change has the potential to change the risk profile for conceptual site models and associated contaminant linkages. The impact of climate change on the CSM is site-specific, and a qualitative assessment of the potential impact of climate change on the CSM for this site is summarised below. The assessment has primarily utilised the guidance in Environment Agency (2010)³ and SoBRA (2022)⁴ which set out the UK context to climate change and land contamination. Both guidance documents advocate a “what if” scenario approach in the context of changes in ambient temperatures, an increase in the frequency of extreme rainfall/storm events and heatwaves/droughts, and long-term changes in groundwater and sea levels.

Those “what if” scenarios that are relevant to this CSM are:

- » Increased long-term rainfall leading to increased infiltration and seasonally higher groundwater and water levels in surface waters.
- » Increased frequency and/or magnitude of storm events leading to short-term drops in barometric pressure and/or high winds.
- » Occurrence of extreme cold and hot weather events leading to changes in ground conditions such as soil temperature, evapo(trans)piration, and soil moisture (for example freeze-thaw effects and desiccation), decreased infiltration and fall in groundwater and surface water levels.
- » Long-term decrease in rainfall leading to lower infiltration and fall in groundwater and surface water levels.

Climate change considerations for the Conceptual Site Model are presented in Appendix G.

³ Environment Agency, 2010. *Guiding Principles for Land Contamination. Part 2. FAQs, technical information, detailed advice and references, March 2010.*

⁴ SoBRA, 2022. *Guidance on Assessing Risk to Controlled Waters from UK Land Contamination Under Conditions of Future Climate Change, Society of Brownfield Risk Assessment, August 2022.*

4. Desk study conclusions

4.1 Geotechnical conclusions

The following plausible geotechnical risks are identified:

- » Variable Made Ground - settlement or differential settlement of foundations, floor slabs, roads and infrastructure elements.
- » Brine solution features and voids– the site is in an area where properties have designated prescribed notices of damage and is underlain by wet rock, potential for voids and dissolution features leading to a loss of support of foundations, roads and pavements.
- » Attack of buried concrete by aggressive ground conditions – the development site may contain Made Ground and potentially sulphate bearing soils.
- » Running sands, loose Made Ground and shallow groundwater, leading to difficulty with excavation due to trench instability.
- » Seasonal Groundwater Variations – there is a moderate risk from groundwater flooding and the shallow groundwater within the Glaciofluvial Deposits could be subject to seasonal variations.
- » Attack of buried concrete by aggressive ground conditions – the development site may contain Made Ground and potentially sulphate bearing soils.
- » Shrinkage/swelling of clay – settlement/heave of foundations, especially where located within the influence of trees and vegetation.
- » Existing retaining walls integrity and impact on foundations, floor slabs, roads and infrastructure and construction plant.
- » Potential for obstructions and the risk of instability of excavations with the impact on construction staff, vehicles and plant operators.
- » Potential for unforeseen ground conditions and the risks associated with limited data.

These plausible risks require further investigation and assessment (see Appendix E).

4.2 Geoenvironmental conclusions

Based on historical and current land uses:

- » Cheshire East Council state that additional investigation is required to confirm if the site is classified as Contaminated Land under Part 2A of the EPA 1990.
- » The overall risk from land contamination at the site is considered to be moderate for the current development, as it is covered by hard standing or buildings limiting the possibility of contact with the soils, as well as the risk of significant rainwater infiltration leading to leaching.
- » The overall risk for a redeveloped site is assessed to be moderate, with some specific potentially high risks, but this would need to be confirmed by appropriate intrusive investigation, testing and assessment of the results of the investigation.

The possible pollutant linkages (for risk levels of moderate or greater) on an unremediated redeveloped site, as determined by the desk study and walk-over, are summarised in Table 4.1:

Table 4.1: Possible Pollutant Linkages (for Risk Levels of Moderate or Greater)

Source(s)	◀ potential Impact on ▶	Receptor(s)
Made Ground, associated with former Gas Holders and Purifier/Oxide Store, possibly including elevated concentrations of metals, metalloids, polycyclic aromatic hydrocarbons (PAH), benzene, toluene, ethylbenzene and xylene (BTEX), complex and free cyanides, thiocyanate, ammonium compounds, sulphate/sulphides, elevated pH, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) (S1)- <i>the previous ground investigation completed by LK Associates confirmed the presence of elevated lead, naphthalene, aromatic hydrocarbons within the backfill of Holder No1, as well as hydrocarbon odours and visual evidence of impact in the underlying Glaciofluvial Deposits. Deeper Made Ground in the vicinity of Holder No1 contains evidence of petroleum hydrocarbon impact.</i>		Site end users (R1). Utilities (R2) Groundwater (R3)
Made Ground associated with the former Abattoir potentially included metals, metalloids, PAHs, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC). (S2)		Site end users (R1). Utilities (R2) Groundwater (R3)
Made Ground, potentially containing asbestos fibres and Asbestos Containing Materials from demolition of former gas works and abattoir structures (S3).		Site end users (R1).
Ground gases (carbon dioxide and methane) from organic materials in the Made Ground (S4).		Site end users (R1). Buildings (R2)

These possible pollutant linkages require further investigation and assessment (see Appendix F).

5. Uncertainties and limitations

5.1 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Knutsford Town Council (the Client), by e-mail dated January 2024 under the terms of appointment for Hydrock, for the sole and specific use of the Client and parties commissioned by them to undertake work where reliance is placed on this report. Any third parties who use the information contained herein do so at their own risk. Hydrock shall not be responsible for any use of the report or its contents for any purpose other than that for which it was prepared or for use of the report by any parties not defined in Hydrock's appointment.

This report details the findings of work carried out in February 2024. The report has been prepared by Hydrock on the basis of available information obtained during the study period. Although every reasonable effort has been made to gather all relevant information, not all potential environmental constraints or liabilities associated with the site may have been revealed.

Hydrock has used reasonable skill, care and diligence in the design of the investigation of the site and in its interpretation of the information obtained. The inherent variation of ground conditions allows only definition of the actual conditions at the locations and depths of trial pits and boreholes at the time of the investigation. At intermediate locations, conditions can only be inferred.

Unless otherwise stated, the recommendations in this report assume that ground levels will remain as existing. If there is to be any re-profiling (e.g. to create development platforms or for flood alleviation) then the recommendations may not apply.

Information provided by third parties has been used in good faith and is taken at face value; however, Hydrock cannot guarantee its accuracy or completeness.

Where the existing report(s) prepared by others have been provided by the Client, it is assumed that these have been either commissioned by the Client, or can be assigned to the Client, and can be relied upon by Hydrock. Should this not be the case Hydrock should be informed immediately as additional work may be required. Hydrock is not responsible for any factual errors or omissions in the supplied data, or for the opinions and recommendations of others. It is possible that the conditions described may have since changed through natural processes or later activities.

The work has been carried out in general accordance with recognised best practice. Unless otherwise stated, no assessment has been made for the presence of radioactive substances or unexploded ordnance. Where the phrase 'suitable for use' is used in this report, it is in keeping with the terminology used in planning control and does not imply any specific warranty or guarantee offered by Hydrock.

Whilst the preliminary risk assessment process has identified potential risks to construction workers, consideration of occupational health and safety issues is beyond the scope of this report.

The non-specialist UXO screening has been undertaken for the purposes of ground investigation only (i.e. low risk activity in accordance with CIRIA Report C681). Further assessment should be undertaken with regards to other higher risk activities e.g. construction.

Please note that notwithstanding any site observations concerning the presence or otherwise of archaeological sites, asbestos-containing materials or invasive weeds, this report does not constitute a formal survey of these potential constraints and specialist advice should be sought.

Any site boundary line depicted on plans does not imply legal ownership of land.

6. Recommendations for further work

6.1 Ground investigation objectives

In order to confirm the actual risks to receptors and confirm the ground conditions with respect to potential geotechnical and geo-environmental risks, an appropriate intrusive investigation will need to be undertaken. This investigation will need to:

- » determine the depth and distribution of Made Ground and natural strata across the site;
- » determine the presence of remaining underground structures;
- » target the specific gas works and abattoir features with investigation to adequately characterise the risk posed to receptors;
- » confirm the presence/absence of voids & dissolution features associated with the Northwich Halite Member following agreement of investigation scope with the Brine Board.
- » determine the soil strength/density profile beneath the site;
- » determine the depth/level of groundwater beneath the site;
- » determine the ground gas concentrations beneath the site;
- » determine CBRs to assist with pavement design;
- » assess trench stability, over break potential and 'diggability';
- » allow soil infiltration rate testing;
- » allow sampling for chemical and geotechnical laboratory testing;
- » confirm the vapour risk posed by volatile contamination potentially within soils and groundwater;
- » allow soil classification to allow geotechnical characterisation and determine suitability for reuse of soils within earthworks;
- » obtain information in terms of Aggressive Chemical Environment for Concrete Class (ACEC Class).

Following investigation, assessment will be required to:

- » update the Ground Model;
- » update the Geotechnical Risk Register;
- » provide Geotechnical Design recommendations;
- » update the Conceptual Site Model (CSM), including identification of plausible pollution linkages;
- » undertake generic quantitative risk assessment of potential chemical contaminants to establish 'suitability for use' under the current planning regime;
- » discuss potential environmental liabilities associated with land contamination (soil, water and gas); and
- » provide outline mitigation recommendations to ensure the site is 'suitable for use'.

7. References

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Appendix A Drawings

National Grid provided Knutsford Gas Works Plans

Appendix B Field reconnaissance photographs

Appendix C Historical ordnance survey maps

Appendix D Desk study research information

Groundsure Geo+Enviro Insight Report

BGS archive records

Regional bomb risk map

Zetica UXB risk maps

*Cheshire East Council Environmental Search- Formal
Response Letter*

Cheshire Salt Search

Appendix E Preliminary geotechnical risk register

Geotechnical hazard identification – desk study stage

Potential geotechnical hazards have been assessed in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622. The following pages set out the identified geotechnical risks and hazards which are associated with the proposed development and establish the approach which is to be taken to manage the risks including the geotechnical input and analysis.

Table E.1 is a preliminary assessment of possible geotechnical hazards at the site at Desk Study stage. This information is used to assist with ground investigation design.

Table E.1: Possible geotechnical hazards

Hazard	Comment	Hazard status based on desk study	
		Could be present and / or affect site (i.e. Plausible)	Unlikely to be present and/or affect site
Uncontrolled Made Ground (variable strength and compressibility).	Extensive Made Ground anticipated due to the historical gas works on site.	✓	-
Soft / loose compressible ground (low strength and high settlement potential).	Unknown composition of Made Ground below the site.	✓	-
Shrink swell of the clay fraction of soils under the influence of vegetation.	Shallow cohesive soils could be present in the Glaciofluvial Deposits.	✓	-
Variable lateral and vertical changes in ground conditions.	Likely deep Made Ground associated with former Gas Holders but shallower under former buildings.	✓	-
High sulphates present in the soils.	Made Ground present across the site.	✓	-
Adverse chemical ground conditions, (e.g. expansive slag).	Unlikely to pose a risk.	-	✓
Obstructions.	Associated former buildings and holders.	✓	-
Existing below ground structures to remain (on or off-site tunnels, foundations, basements, and adjacent sub-structures).	The below ground Gas Holder infrastructure will likely be grubbed out and removed.	-	✓
Shallow groundwater.	Shallow groundwater likely to be present within the glaciofluvial deposits.	✓	-
Changing groundwater conditions.	The groundwater within the Glaciofluvial Deposits may not be confined and subject to seasonal variations.	✓	-
Risk from erosion.		-	✓

Hazard	Comment	Hazard status based on desk study	
		Could be present and / or affect site (i.e. Plausible)	Unlikely to be present and/or affect site
Risk from flooding.	Not anticipated to be a hazard.	-	✓
Running sands, leading to difficulty with excavation and collapse of side walls.	Potentially a hazard if shallow groundwater is present within the Glaciofluvial deposits.	✓	-
Slope stability issues – general slopes.	The site slopes gently from the north west to the site entrance in the south east.	✓	-
Slope stability issues – retaining walls.	There is a retaining wall on the eastern boundary of brick construction. The conditions of the retaining wall should be assessed.		
Earthworks – settlement (due to placement of fill on soft / loose ground).	The site is relatively flat and any remaining voids within the below ground holder will likely be backfilled within a geotechnical and chemically suitable imported fill.	-	✓
Earthworks – poor bearing capacity of new fill.			
Earthworks – unsuitability of site won material to be reused as fill.			
Dissolution (associated with “wet rock head”).	The site is underlain by the ‘wet rock’ the Northwich Halite Member and dissolution features are present within 200m of the site. Properties adjacent to the north west of the site have prescribed damage notices.	✓	-
Brine extraction.	No current or historical brine extraction in close proximity to the site.	-	✓
Mining.	Not anticipated to be a hazard.	-	✓
Relict Slip Surfaces.			
Solifluction.			

Appendix F Plausible source- pathway-receptor contaminant linkages

Summary of potential contaminant linkages

Table F.2 lists the plausible contaminant linkages which have been identified. These are considered as potentially unacceptable risks in line with guidelines published in LCRM (2023) and additional risk assessment is required.

Source – Pathway – Receptor Linkages have been assessed in general accordance with guidance in CIRIA Report C552 (Rudland *et al* 2001) but modified to add a 'no linkage' category and to remove low/moderate risk (See Table F.1).

It should be noted that whilst the risk assessment process undertaken in this report may identify potential risks to site demolition and redevelopment workers, consideration of occupational health and safety issues is beyond the scope of this report and need to be considered separately in the Construction Phase Health and Safety Plan.

Table F.1: Consequence versus probability assessment.

		Consequence			
		Severe	Medium	Mild	Minor
Probability	High Likelihood	Very high risk	High risk	Moderate risk	Low risk
	Likely	High risk	Moderate risk	Low risk	Very low risk
	Low Likelihood	Moderate risk	Low risk	Low risk	Very low risk
	Unlikely	Low risk	Very low risk	Very low risk	Very low risk
	No Linkage	No risk			

Table F.2: Exposure model –source-pathway-receptor model

Sources	Possible Pathways	Receptors	Probability	Consequence	Risk Level	Comments
Made Ground, associated with former Gas Holders and Purifier/Oxide Store, including elevated concentrations of metals, metalloids, polycyclic aromatic hydrocarbons (PAH), benzene, toluene, ethylbenzene and xylene (BTEX), complex and free cyanides, thiocyanate, ammonium compounds, sulphate/sulphides, elevated pH, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) (S1).	Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).	People (site end users) (R1).	Likely	Medium	Moderate	Gas Holders, Purifiers and an Oxide Store were present on the site and the Made Ground associated with these former uses is likely to contain elevated concentrations of contaminants harmful to human health. Previous ground investigation confirmed elevated spent oxide (cyanide) impacted hardcore in TP4. Shallow odours associated with tar were also encountered, as well as solid tar to the east of Holder No1 between 0.3m and 2.3m bgl. Lead and Naphthalene impacted backfill in Holder No1.
	Direct Contact with Water Pipes (P2)	Water Pipelines (R2)	Likely	Medium	Moderate	The Made Ground or natural soils at the depth of proposed pipelines may contain elevated concentrations of petroleum hydrocarbons/ VOCs and SVOCs at concentrations above the PE threshold given the sites former use. As part of the ground investigation samples should be collected from proposed pipeline depths to allow for a water pipeline risk assessment to be completed.
	Migration of contaminant via leachate migration through the unsaturated zone in the Glaciofluvial deposits (P5).	Groundwater: Secondary A aquifer status of the Glaciofluvial deposits (R3).	Likely	Medium	Moderate	<p>Previous ground investigation confirmed significant hydrocarbon impacted Made Ground at circa 5.00m bgl. The dumping in Holder No1 unlike Holder No2 includes a 0.80m lining of stiff sandy CLAY, therefore hydrocarbons/phenols/BTEX associated with the tar impacted soils have migrated into the natural Glaciofluvial Deposits.</p> <p>The Glaciofluvial deposits are classified as a Secondary A aquifer. Leaching/dissolved phase migration of contaminants through the unsaturated zone in potentially granular Made Ground and permeable Glaciofluvial Deposits is likely to have occurred.</p> <p>The ground investigation should establish the contamination extent in the groundwater.</p>

Sources	Possible Pathways	Receptors	Probability	Consequence	Risk Level	Comments
Made Ground associated with the former Abattoir potentially included metals, metalloids, PAHs, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC). (S2)	Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).	People (site end users) (R1).	Likely	Medium	Moderate	An abattoir was present in the south east of the site. The Made Ground associated with this former use is likely to contain elevated concentrations of contaminants harmful to human health. The ground investigation should include targeted chemical analysis and characterisation of the Made Ground associated with these former uses.
	Direct Contact with Water Pipes (P2)	Water Pipelines (R2)	Likely	Medium	Moderate	The Made Ground or natural soils at the depth of proposed pipelines may contain elevated concentrations of petroleum hydrocarbons/ VOCs and SVOCs at concentrations above the PE threshold given the sites former use. As part of the ground investigation samples should be collected from proposed pipeline depths to allow for a water pipeline risk assessment to be completed.
	Migration of contaminant via leachate migration through the unsaturated zone in the Glaciofluvial deposits (P5).	Groundwater: Secondary A aquifer status of the Glaciofluvial deposits (R3).	Likely	Medium	Moderate	Leakages/uncontrolled disposal/storage/burial or spillages of dissolved/leachable contaminations may have occurred during the operation of the abattoir. The Glaciofluvial deposits are classified as a Secondary A aquifer. Leaching/dissolved phase migration of contaminants through the unsaturated zone in potentially granular Made Ground and permeable Glaciofluvial Deposits is likely to have occurred. As part of the ground investigation targeted groundwater monitoring wells should be installed to allow for characterisation of the current conditions,

Sources	Possible Pathways	Receptors	Probability	Consequence	Risk Level	Comments
Made Ground, potentially containing asbestos fibres and Asbestos Containing Materials from demolition of former gas works and abattoir structures (S3).	Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).	People (neighbours, site end users) (R1).	Likely	Severe	High	Asbestos may be present in Made Ground from the demolition of the gas works infrastructure and abattoir. The presence of asbestos containing material within the Made Ground should be investigated and asbestos testing should be completed on samples of Made Ground. During the ground investigation and construction phase management of asbestos risk in accordance with CAR SOILs should reduce the risk to neighbours to low.
Ground gases (carbon dioxide and methane) from organic materials in the Made Ground (S4).	Methane and carbon dioxide ingress via permeable soils and/or construction gaps (P3).	People (site end users) asphyxiation (R1)	Low Likelihood	Severe	Moderate	Holder No.1 contains organic deposits and degrading material within its backfill and the previous ground investigation confirmed significantly elevated methane and carbon dioxide associated with the backfill in Holder No.1. Ground gas monitoring is advised to establish the gas regime at the site. Enclosed spaces within the proposed end use could be at risk from ground gas entry and build up.
		Build of hazardous gas explosion (R2)	Low Likelihood	Severe	Moderate	
Vapours from potential VOCs, BTEX and petroleum hydrocarbon spillages/leaks associated with the former Gas Works and Abattoir (S5).	VOC and petroleum hydrocarbon vapour ingress via permeable soils and/or construction gaps (P4).	People (site end users) asphyxiation (R1)	Unlikely	Severe	Low	Made Ground beneath the site could contain shallow light end contamination/BTEX and VOCs which could produce hydrocarbon vapours or volatile compound due to the historical gas works at the site. However, given the site since closure of the gas works it is likely that volatiles will have degraded and diminished over time to concentrations below those harmful to human health. The previous ground investigation concluded a low vapour risk posed by the hydrocarbon impacted soils at depth >5.00m bgl. Enclosed spaces within the proposed end use could be at risk from vapour build up.
		Build of hazardous gas explosion (R2)	Unlikely	Severe	Low	

Sources	Possible Pathways	Receptors	Probability	Consequence	Risk Level	Comments
PCBs and oils from the electricity substation to the north of the site (S6).	Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).	People (site end users) (R1).	Low likelihood	Medium	Low	The electrical substation is located north east of the site and given that the groundwater is likely to flow east. Any PCBs from the electrical substation will migrate east away from the site and therefore will not pose a risk to human health or groundwater beneath the site.
Migration of contaminants from the offsite wider Knutsford Gas Works, associated with the Tar and Liquor Wells possibly including elevated concentrations of benzene, toluene, ethylbenzene and xylene (BTEX), complex and free cyanides, thiocyanate, ammonium compounds, sulphate/sulphides, elevated pH, petroleum hydrocarbons, volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) (S7)	Migration of contaminant via leachate migration through the unsaturated zone in the Glaciofluvial deposits (P5).	Groundwater: Secondary A aquifer status of the Glaciofluvial deposits (R3).	Low likelihood	Medium	Low	Groundwater within the surrounding area and beneath the site is likely to flow east. Therefore, mobile contamination from the offsite gas works infrastructure (including tar wells and liquor wells) could migrate beneath the site. Given the permeability of the underlying Glaciofluvial Deposits its unlikely to be at depth to pose a risk to human health via direct contact or vapours. However groundwater monitoring within the south west could find elevated concentrations from these legacy features. These features have previously been demolished and assumed remediated, so therefore if found and proven as emigrating from an offsite source, there is unlikely to be any remedial action that could be undertaken on the existing site to remedy these concentrations in the groundwater,

Appendix G Climate change considerations for CSM

Table G.1 summarises the considerations that have been made in relation the possible implications of predicted climate change. These considerations have been made with reference to prevailing guidance on climate change and land contamination (SoBRA (2022), CL:AIRE (2022), Environment Agency (2010)), and climate change information published by the Met Office and the Environment Agency / NRW / SEPA.

Table G.1: Possible CSM considerations related to climate change

Climate change type	Potential climate change induced effect	Possible considerations on CSM
Increase in frequency and severity of extreme rainfall events	Temporary increasing in groundwater levels	It is possible that future groundwater level rise could be sufficient to impact identified contaminant linkages. The risk of groundwater flooding is increased but is unlikely to result in a groundwater flooding given the current depth to groundwater. Vapour intrusion vertical screening distance for dissolved phase hydrocarbons is reduced and therefore could be screened in as a contaminant linkage requiring further assessment. The presence of a LNAPL layers on the groundwater surface and the predicted rise in groundwater levels is likely to result in the movement of the LNAPL closer to the ground surface or sub-surface infrastructure and create a larger NAPL smear zone.
	Increased surface run-off	Site is covered in concrete hardstanding/landscaping with associated surface water drainage. Surface water run-off will impact drainage network (in terms of volume of water) but is not expected to impact underlying ground conditions.
	Land-based erosion	Unlikely, given of the proximity of the site to the River Lily (190m east). River bank erosion caused by extreme river level events is not considered plausible.
	River flooding	The site is located within a Flood Zone 1, risk of flooding (low probability). An increase in frequency and severity of extreme rainfall events is unlikely to change the risk posed by river flooding given the distance to between the site and the River Lily (190m east).
Increase in frequency and severity of extreme cold and hot weather events	Soil freezing	Could cause failure of surface water drainage network (requiring repair) due to freeze/thaw action but not evident that this would cause a significant change to identified contaminant linkages.
	Soil desiccation/shrinkage	The cohesive nature of superficial deposit (Glacial Till) suggests a risk from shrinkage-related subsidence could become plausible.

Climate change type	Potential climate change induced effect	Possible considerations on CSM
	Land fires	Not relevant to current nature and location of site.
	Temporary drop in water (GW and/or SW) levels due to increased water abstraction demand	Underlying aquifer does not have any licenced abstractions registered within 1km of the site. Impact of a drop in water levels in the Secondary A Aquifer not expected to adversely affect identified contaminant linkages.
	Temporary drop in water levels (GW and/or SW) due to lower rainfall.	Water levels in the shallow aquifer may fall further in drier summer months. This will increase the thickness of the LNAPL smear zone and could result in greater soil vapour flux as a result of the greater thickness of unsaturated LNAPL-contaminated soil present. This significance of this is dependent on the current level of risk identified for vapour intrusion. A subsequent rise in groundwater level and re-saturation of the LNAPL smear zone could course a short-term increase in dissolved phase PHC concentrations.
Long-term sea level rise	Coastal erosion	The site is not within a coastal area and therefore will not be affected by coastal erosion.
	Saline intrusion and marine inundation	The site is not within an area whereby groundwater is under tidal influence and therefore not considered to impact the site.
Long-term increase in rainfall	Increase in groundwater levels	The site is located within a river catchment that eFLAG predicts will see an increase of 0.90mm per day in groundwater recharge in winter months. This could result in a potential increase in the groundwater table within the Glaciofluvial Deposits,
Long-term decrease in rainfall	Decrease in groundwater levels	See comment above for temporary decrease in groundwater levels above. Whilst it is expected that there will be an increase in winter rainfall it is also expected that there will be a reduction in summer rainfall such that there will be a long-term increase in the expected seasonal fluctuation in shallow groundwater depth. The seasonal movement of groundwater across the LNAPL smear zone could act to increase the rate of long-term natural source zone depletion of the LNAPL.
Long-term change in seasonal temperatures	Change in soil temperature	Worst-case (RCP8.5) prediction for average summer temperatures in 2060-2080 in this area is 5-6 degrees Celsius. Soil temperature at depth below the site (considering the surface cover of buildings and concrete hardstanding) is not expected to rise by this amount and may see a much smaller rise in average temperature as a result of seasonal variation in temperature.