



NQMS SQP Declaration of Document Adequacy

Project

Project Name NGET Arriva Bus Depot, Tottenham
Project Address Leaside Road, Tottenham, N17 0SG
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Summary Description of Project / Proposed development

The site is owned by National Grid Property Holdings Ltd and was formerly leased to a third party. The site is due to be developed in association with a substation upgrade as part of the North London Reinforcement Project. The objectives of the report were to refine the conceptual site model with regards to controlled waters based on available data and to undertake a controlled waters detailed quantitative risk assessment to assess potentially unacceptable risks to controlled waters. The outcomes of the CWDQRA will form the basis for remediation measures to be detailed in a separate Remediation Strategy.

Document

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Controlled Waters Detailed Quantitative
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Regulator's Contact Details

Local Authority Details

Local Authority Name	N/A
Contact Name	N/A
Contact Telephone	N/A
Contact Email	N/A
Contact Role	N/A

Regulator Details

Regulator	Environment Agency
Contact Name	George Lloyd
Contact Telephone	N/A
Contact Email	HNLSustainablePlaces@environment-agency.gov.uk
Contact Role	Planning Advisor

SQP Details

SQP Name	Chris Hughes
SQP Registration No.	SQP0136
Telephone	07723373265
Email	chris.hughes@atkinsrealis.com
Organisation	AtkinsRéalis
Address	27 Derbyshire Road, , Sale, M33 3FD
Chartered or Professional Institution	Institution of Environmental Sciences
Chartered or Professional Institution	
Membership Reference	



Declaration

I, Chris Hughes, confirm that I am the person described in the SQP Details section and hold current valid registration as a Suitably Qualified and Experienced Person Registration No. SQP0136 with the NQMS.

I have reviewed the document described in the Document Details section, in relation to the project and site described in the Site Details section, and I am satisfied that:

1. The assessment has been carried out by appropriately capable people with reference to the Brownfield Skills Framework.
2. That the assessment carried out is, to the best of my knowledge, undertaken with reasonable skill and care, and the information and data reported:
 - i. describe an appropriate scope and objectives and
 - ii. accord with relevant good practice guidance and standards and
 - iii. are based upon appropriately robust science and
 - iv. are factually correct and
 - v. have been appropriately reviewed.
3. That all specialist aspects have been reviewed by an appropriately qualified/competent person with relevant skills and experience in that specialist area.
4. That the interpretation and conclusions are reasonable.
5. That proposals to mitigate actual, potential, or residual risks are appropriate (where relevant to the report type).
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 - b. The work of this review and Declaration are within the limits of my knowledge, competence and professional capacity.

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0124-H9838

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Name:
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NGET Former Bus Depot, Tottenham (8021)

Controlled Waters Detailed Quantitative Assessment Report

National Grid Electricity Transmission

February 2024

Notice

This document and its contents have been prepared and are intended solely as information for National Grid Electricity Transmission (NGET) and National Grid Property Holdings (NGPH) in relation to providing a detailed quantitative risk assessment for the NGET Former Bus Depot located off Leaside Road, Tottenham, N17 0SG.

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Document history

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1.0	Draft for comment	KB	TW	DC	CH	November 2023
2.0	Updated draft following client comments, design changes and Environment Agency engagement.	KB	LI	DC	AN	February 2024

Client signoff

Client	National Grid Electricity Transmission
Project	NGET Former Bus Depot, Tottenham (8021)
Job number	5225197
Client signature/date	

Document Details



Site Address	Leaside Road, Tottenham, N17 0SG	NGP Document Tracking code	
Report Title	Controlled Waters Quantitative Assessment Report		
Report Type	Contamination	Retention Period	Indefinitely
Site Code	8021	Author (Company)	AtkinsRéalis
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Version	V2.0	H&S File?	Yes
Draft/Final	Final	NGET Contact	LRA. Charlotte Foster LRM. Simon Dunstan
Brief Description of Contents	Interpretative report for the data obtained from the intrusive site investigation conducted in April 2023 across the former bus depot site, now used as a building and plumbing merchants, and a steel fabricators, in Tottenham (Site Code: 8021).		
Work Stage	Site Investigation	Access Permitted	NGET Land Regeneration Team

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1. Introduction

1.1. General

AtkinsRéalis Limited (AtkinsRéalis) has been commissioned by National Grid Electricity Transmission (NGET) to complete a controlled waters detailed qualitative risk assessment (CWDQRA) for the NGET Former Bus Depot, Leaside Road, Tottenham, N17 0SG (herein referred to as 'the site').

This report has been produced in accordance with AtkinsRéalis Offer of Services dated 31 August 2023.

This report A Site Location Plan is included as Figure 1 and a Site Layout Plan is included as Figure 2.

1.2. Background

The site is located off Leaside Road, Tottenham, London and is situated in the north-east of the Mowlem Trading Estate, approximately 1.5 km to the east of Tottenham. The site was formerly leased to Arriva for use as a bus depot, and currently comprises a building and plumbing merchants, steel fabricator and logistics yard.

The site is proposed for redevelopment as part of the wider North London Reinforcement Project (NLRP), which will see the site redeveloped to facilitate an upgrade to the adjacent NGET owned substation to the east and south. It is understood that the lease on the site is ending in early 2024.

This CWDQRA aims to support the partial discharge of Requirement 11 as outlined in the Document Consent Order (DCO) 2014 No. 1052 North London Reinforcement Project [1], for Stage 3a of the development works. This report has been prepared in line with relevant guidance such as the National Planning Policy Framework (NPPF) [2], Land Contamination Risk Management (LCRM) [3] and pre-application advice (discussed below).

Stage 3a of the works constitutes the preparatory stages of work to clear the site and demolish the on-site structures, to enable Stages 3b and 4 to take place. Stages 3b and 4 comprise the construction of the infrastructure to upgrade the adjacent substation. The Tottenham Substation forms part of the NLRP to upgrade the 275kV overhead lines between Waltham Cross and Tottenham, to a higher voltage (400kV).

Requirement 11 of the DCO stipulates that consultation with the Environment Agency (EA) must be carried out prior to any submission of documentation to the planning authority. A meeting was held between the EA and AtkinsRéalis in December 2023 and the minutes prepared by the EA and AtkinsRéalis subsequent to the meeting are included in Appendix G. Actions agreed with the EA during this meeting have been incorporated into this CWDQRA.

This report forms part of a package of four documents that will be submitted to support the discharge of Requirement 11 of the DCO, ahead of the proposed demolition of the former depot building. The reports are listed below:

- Atkins, NGET Arriva Bus Depot, Tottenham (8021). Factual Site Investigation Report. 2023. [4]
- Atkins, NGET Arriva Bus Depot, Tottenham (8021). Interpretative Site Investigation Report. 2023. [5]
- Atkins, NGET Arriva Bus Depot, Tottenham (8021). Remediation Strategy. 2024. [6]

These reports should be sought for full details on the site and any pertinent details are summarised in the report.

1.3. Proposed Development Phases

As part of the NLRP, it is proposed that the current buildings on site are demolished, and the site redeveloped to accommodate the upgraded network. The site will be a cable sealing end compound between two sections of underground cables. It is the understanding that works at the site will be undertaken in the following stages and are likely to comprise:

- Demolition (Stage 3a) - removal of all above ground infrastructure from the site and the excavation of clean corridors for the future placement of cables, it is understood that this stage will remove hard standing where required;
- Remediation (Stage 3a) – remediation of the site as per the Remediation Strategy [6];
- Construction (Stages 3b and 4) – installation of all infrastructure within clean corridors; and
- Operation – during operation, access to the site will be heavily restricted.

1.4. Scope of Assessment

The key objectives of this report are:

- to refine the conceptual site model regarding controlled waters, based on all available data; and
- produce a CWDQRA to assess the current potentially unacceptable risk to controlled waters from impacted soil and groundwater during baseline and future (construction/ operation) stages of the development. These identified potentially unacceptable risks to controlled waters will form the basis of the remediation, specified in the Remediation Strategy [6].

1.5. Assumptions and Limitations

The key assumptions and limitations associated with this work are as follows:

- the CWDQRA addresses risks to controlled waters only. Other receptors such as humans or property (e.g. buildings) lie outside the scope of this report;
- geology, by its very nature, is both laterally and vertically variable and could be dissimilar from that identified within the exploratory holes completed to date;
- data from previous site investigations, undertaken by third-parties have been incorporated into this report. These data have been assumed to be correct for the purposes of this assessment;
- the assessment relies upon available third-party historical data for the site and adjacent sites. AtkinsRéalis accepts no responsibility for the limitations and constraints in the assessment associated with the use of third-party data, but, where identified, this limitation has been considered within the assessment;
- climate change impacts to the site have been considered in the modelling for the quantitative risk assessment based on the UKCP18 projections, current at the time of writing. Any future changes to climate change projections which may significantly alter the relevant modelling parameters have not been accounted for;
- Much of the data used in the assessment herein was obtained in 2013. Given that potentially contaminative sources at the site predate the 2013 investigation the data is still considered valid. Inherent limitations associated with the age of the data may be present;
- AtkinsRéalis have commenced engagement with the Environment Agency, this is ongoing and updates of this report will be completed as necessary.

2. Site Setting

2.1. General

The site is located off Leaside Road, Tottenham, North London N17 0SG and situated in the north-east of the Mowlem Trading Estate, approximately 1.5 km east of Tottenham centre and located approximately 300 m west of Banbury Reservoir at Ordnance Survey (OS) National Grid Reference: 535413E, 191516N further reservoirs are located north and south of the site. The average elevation of the site is 10 metres above Ordnance Datum (m AOD), with the topography of the land being generally flat with minor localised dips. The site covers an area of 1.2 hectares (ha) within a rectangular parcel of land. A site location plan is presented as Figure 1.

2.2. Current Site Layout

The site is accessed from Leaside Road, north-east of the Mowlem Trading Estate. The boundary of the site is secure and comprises an approximately 2.5 m high steel palisade fence with access via a double steel palisade gate from Leaside Road. There are a variety of internal palisade fences throughout the site to segregate current operations.

The site includes several active commercial units housed within a two-storey, rectangular, brick building, with steel cladding exterior and an adjacent concrete/tarmac storage yard. Within the site boundary there is a small brick structure in the west of the site that appears to be a maintenance/security hut.

The site is currently leased from National Grid Electricity Transmission (NGET) to J O'Doherty Group, which uses the southern third of the site for the storage/parking of empty waste skips, vehicles, trailers and storage of tonne-bags of aggregates. J O'Doherty Group sub-lets the northern two thirds of the site to three businesses, the following site uses are understood to have been utilised on this area:

- The majority of the northern two thirds of the main building and two-yard areas are sub-leased to Build It Limited, which is a builder's merchants, and a plumbing merchants. Build It Ltd use the lower floor of the building for trade and the upper level is used as office space/storage. The yard areas are used for materials storage, parking and for storage waste.
- The southern third of the building and some adjacent yard space is sub-let to Lomas Steel Structures Limited for metal fabrication.

The steel fabricator's yard, present to the south of the main depot building, is used for spray coating primer and treating the steel under an external shelter. The primer used 'Red Oxide' and is understood to be flammable, an irritant and a potential carcinogen. The underlying concrete, surrounding fencing and shelter have been sprayed red in this area.

No electricity transmission infrastructure is present on-site; however, the site is directly north of an active substation. No fuel storage tanks are currently housed onsite.

High voltage overhead cables and pylons are present in the land immediately to the east.

A site layout plan is presented as Figure 2.

2.2.1. Current Ground Cover

The majority of the site is covered in concrete hardstanding or buildings / structures. Minor vegetative growth, comprising grasses and shrubs, is present adjacent to the north of the site and there is no visual evidence at the time of this report (January 2024) of any invasive species around the site boundary. A summary of ground cover currently present at the site is presented in Table 2-1 below.

The site is covered by hardstanding. It is assumed that run-off is managed appropriately within the hardstanding construction and infiltration through the soil is not anticipated. As a result, any soil pathway has been excluded from the baseline assessment.

Table 2-1 – Summary of Ground Cover

Total Site Area:	1.20 ha (approximately)
Type	% Area (approximately)
Concrete Hardstanding	80
Buildings	20

2.3. Development

A summary of how the development is considered to change the site ground conditions related to this assessment are included below. The exact layout and scope of each phase are yet to be fully defined.

2.3.1. Remediation

Surface cover will be removed with the scope detailed in the remediation strategy. Potential construction risks to controlled waters receptors associated with the remediation will be discussed separately and are considered to be outside the scope of this assessment.

It is however noted that all concrete arising from the demolition phase will be crushed and used as ground matting across the site. This crushed concrete layer has been assumed to provide a capping layer which will ensure that run off from the site does not contain sediment from the site. As such this pathway will not be considered during post remediation phases.

2.3.2. Construction

It is understood that earthworks at the site will consist of the excavation of cable trenches, these trenches will likely be backfilled with crushed concrete or some other aggregate. It is understood that no piling works or excavations deeper than 3.5 metres will take place at the site during construction.

2.3.3. Operation

Based on the proposed remediation/construction, it is assumed that during operation the ground cover at the site will consist of crushed concrete or another type of aggregate.

2.4. Site History

Full details on the history of the site and the surrounding area are included in the Atkins Factual Report [4]. A summary is provided below and a historical features plan is provided as Figure 3.

2.4.1. On-site Development

The earliest available historical map from 1872-1873 shows that the site was predominately undeveloped land, with a drainage ditch crossing the site in 1935. There were no significant changes until 1955. By 1955 – 1956 a pond is shown to be present in the south of the site. By 1967 buildings are shown in the north-west corner of the site and a square pond, in the southern half of the site, is present to the north of the already existing pond.

Between 1967 and 1981 the buildings in the north-west corner were demolished and a large rectangular building was constructed in the north-east corner, understood to form Leaside Works. Several smaller rectangular buildings appeared along the eastern boundary and centre of the site, and the ponds are no longer present on-site, and are assumed to have been infilled.

There were no significant changes to the site area between 1981 and 1991.

Between 1991 and 2001 the site layout has changed, and all previous buildings have been demolished and a long rectangular building was constructed in the north-east corner of the site. An above ground tank was shown to the south of this building and a small rectangular feature along the western site boundary.

Historical mapping for the site dated 2003 (1:1,250) indicates that there is a tank located in the central eastern extent of the site, to the south of the main building. It is stated in the WorleyParsons 2013 report [7] that there

was a underground storage tank located in this position; however, it has not been possible to establish whether the tank is underground or above ground.

No significant changes are shown on-site between 2001 to the present day, however the above ground tank south of the main building appears to have been removed. It is understood that the site was used as a bus depot until circa 2016.

2.4.2. Off-site Development

The historical maps available from circa 1868 to 1920 show the adjacent site area mainly to be undeveloped open fields.

The 1872-1873 OS plan shows an un-named brook along the east boundary of the site (later mapped as Pymmes Brook). The Lee Navigation (River Lee) is located approximately 260 m east of the site, parallel with the brook. A Rifle range is located between the brook and the Lee Navigation. The Great Eastern Railway is mapped approximately 350 m west of site running a north-north-east to south-south-west orientation. Tottenham and Edmonton Gasworks (TEGW), including several tanks and gas holders is mapped approximately 370 m north-west of the site. Tottenham Marsh and Wild Marsh are shown immediately east and south-east of the site.

The 1894 map shows that the TEGW was expanded to feature more gas holders, a nursery was constructed 270 m west, and new industrial sites were erected approximately 500 m north.

By 1920 large-scale industrial features had been constructed in the land to the north and east; the TEGW expanded northwards and a new gasworks (Gothic Works) was established approximately 115 m north of the site. The Banbury reservoir was built approximately 370 m east of site.

Mapping from 1935 shows a small pond immediately south-east of the site and a gas holder was built immediately north of the site. The rifle range to the east of the site was converted into a recreation ground around this time. The 1935 map shows the first appearance of the gas holder located directly north of the site.

The historical OS maps show that between 1938 and 1952 the pond immediately south-east of site had extended and several tanks and ancillary buildings were constructed around the gas holder immediately north of the site. Railway sidings were constructed along the Great Eastern Railway approximately 350 m west of site.

Between 1952 and 1957 unspecified tanks are mapped at the adjacent land to the northeast. Several subsequent maps through to 1991 label this area as 'tanks'.

The 1956 map shows an area to the northwest of the site labelled as 'Leeside Depot'. Several new industrial units were built within 200m west of the site by 1957.

Between 1957 and 1967 an electricity transformer station was built immediately south of the site comprising three buildings to house electrical infrastructure. Three electricity towers were constructed immediately adjacent to the eastern site boundary. The 1967 map also shows an 'Electricity Transfer Station' is present adjacent to the southern boundary.

By 1969 the Leeside civil engineering depot expanded with warehouse buildings and additional tanks. Leeside Chemical Works was mapped approximately 100 m north of the site adjacent to the gas holder.

Between 1967 and 1981 Leeside Depot was redeveloped into Mowlem Trading Estate, with multiple commercial units built immediately west of the site. The chemical works north-east of the site was removed.

Mapping from 1988 shows that several industrial features adjacent to site were removed, including parts of the gasworks north of site. Mapping from 2001 shows that part of the gasworks 500 m north of the site was converted into a superstore.

According to the available historical maps, the gas holder north of site had been removed between 2010 and 2022. Aerial imagery shows the gas holder present on site in July 2014 and being infilled/remediated in April 2015 with works completed in August 2017. Some additional warehouses were constructed approximately 500 m north and north-east of site, within the former industrial works area.

2.5. Geology

A summary of the geology underlying the site is provided below, based on a review of available resources and is detailed fully in the Atkins 2023 Factual Report [4]. Figure 4 presents historical and recent investigation location at the site, while Appendix A presents all available geological logs. Two cross sections interpreting the geology are included as Figure 6 and 7.

2.5.1.1. Made Ground

During the April 2013 WorleyParsons site investigations [7] [8], Made Ground was encountered within all exploratory holes to a maximum depth of 4 m bgl and comprised gravelly SANDS with fine to coarse, subangular to subrounded gravel of concrete, brick, chalk, and sandstone, with glass, wood, slag, and clinker also recorded. Concrete obstructions were recorded in several positions. The layer extended to a maximum depth of 4.0 m bgl.

Within the August 2013 site investigation, Made Ground was encountered within all exploratory holes from ground level to a maximum depth of 6.0 m bgl comprising clayey sands and gravels containing brick concrete, flints, clinker, ash and other debris.

During the AtkinsRéalis 2023 site investigation [4], Made Ground was encountered within all exploratory holes to a maximum depth of 5.3 m bgl consisting of gravelly clayey SAND, gravelly sandy CLAY and gravelly SAND. Made Ground was noted to include concrete, flint, glass, clinker, tiles, coal, chalk and wood.

Deeper instances of Made Ground correspond with the historical infilled pond locations in the south of the site.

2.5.1.2. Superficial Geology

The site is indicated to be underlain by Alluvium (clay, silt, sand and gravel) which overlies the River Terrace Gravel deposits (RTD), namely the Kempton Park Gravel Member (Sand and Gravel).

Alluvium was encountered to a maximum depth of 5.85 m bgl during all onsite ground investigations and comprised soft to very stiff brown/grey silts and clays with some sand and gravel with occasional bands of peat or sand. Alluvium is not present within the southern portion of the site in the vicinity of the pond that was present between 1950-1960.

Kempton Park Gravels (River Terrace Deposits) was found to a maximum depth of 7.8 m bgl during all onsite ground investigations and comprised grey and brown sandy gravel with layers of silt and occasional thin bands of silty clay. Gravels consisted of fine to coarse, angular to rounded flint, quartz, and sandstone in a sandy matrix.

2.5.1.3. Bedrock Geology

The site is underlain by London Clay Formation which is regionally extensive and thins towards the south.

Site investigations encountered London Clay bedrock beneath the Kempton Park Gravels which comprised soft to stiff, fissured, grey and brown clay. The full thickness of London Clay Formation was not proven onsite. Borehole BH2 drilled 153 m to the south of the site beyond the Substation reached the base of the London Clay at approximately 19 m bgl.

The London Clay Formation is underlain by the Lambeth Group comprising clay, silt and sand followed by the Thanet Formation of sand and then the White Chalk Group. The BGS exploratory hole record TQ39SE196, located 195 m east of the site indicates the London Clay Formation extending to 15.2 m depth, underlain by Lambeth Group to a depth of 30.5 m. The Thanet Formation was found to a depth of 39.0 m and this is underlain by the Chalk extending to the base of the borehole at 152.4 m depth.

2.5.1.4. Ground Workings

The Atkins 2023 Factual Report [4] records two historical surface ground working areas identified as ponds on-site. The historical pond was located at the site, with approximate dimensions of 30 m shown in Figure 3. The pond is thought to have been infilled with Made Ground.

2.6. Hydrogeology

The Atkins 2023 Factual Report [4] details that the superficial RTD present in the area are classified as a Secondary A aquifer, defined by the Environment Agency as “*Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers*”. The bedrock London Clay Formation is classified as an unproductive strata, defined by the Environment Agency as: “*rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow*”. The Alluvium is classified as a secondary undifferentiated aquifer, the Environment Agency defines these as ‘*aquifer where it is not possible to apply either a secondary A or B definition because of the variable characteristics of the rock type*’.

Beneath the London Clay the deeper bedrock strata of the Lambeth Group and Thanet Formation are classified as secondary A aquifers and the Chalk as a principal aquifer.

The groundwater vulnerability of the superficial aquifers is recorded as high and the bedrock vulnerability (London Clay) is classified as unproductive.

2.6.1. Groundwater Level Monitoring

Groundwater monitoring at the site and wider area has been completed on four occasions in 2013 and on four occasions in 2023. A full record of groundwater results is presented in Appendix B. Levels recorded in July 2023 have been presented on Figure 5.

Given the narrow rectangular shape of the site and the absence of suitable data, we have assumed there is a continuous groundwater body above the London Clay. It has not been possible to develop groundwater contours and certainty over the groundwater flow direction.

Recorded groundwater levels in the Made Ground (with Alluvium is present beneath the Made Ground) ranged between 0.74 m bgl (9.84 m AOD) in WS12-02 located in the southern portion of the site in the area where the historical pond is located, and 1.94 (8.61 m AOD) at WS12-06 located and in the centre of the site. It is expected that groundwater in the Made Ground is continuous as shown in Figures 6 and Figure 7, groundwater levels generally appear to increase in the south of the site (approximately 0.35 m in WS12-01 and 0.8 in WS12-02) in the Summer of 2023 over four monitoring visits. At this stage, it is not clear if there is a rising groundwater trend.

Recorded groundwater levels in the RTD between 2.56 m bgl (7.59 m AOD) in the north of the site in BH12-06 and 4.27 m bgl (6.26 m AOD) in BH6 located on the Wild Marsh West, south-east of the site.

Groundwater levels recorded in monitoring wells which screen both the Made Ground and the RTD (with no low permeable Alluvium present) ranged between 1.99 m bgl (8.80 m AOD) in BH12-01 and 2.89 m bgl (7.60 m AOD) in BH23-04. Both wells are located within the historical pond.

2.6.2. Groundwater Flow

Based on groundwater level data there is considered two different groundwater bodies onsite, one in the Made Ground and one in the RTD. Groundwater levels indicate that groundwater within the RTD has a southerly and easterly flow component. Where the Alluvium is present the two water bodies report separate groundwater levels with levels in the Made Ground higher than the RTD indicating a downward hydraulic gradient.

Based on the heterogeneity of the Made Ground and observed water levels within the unit any flow within the unit is likely to be irregular. Due to the absence of the low permeable Alluvium groundwater within the RTD and Made Ground is likely to be in hydraulic connection within the vicinity of the historical pond.

Approximately 12 m of London Clay is considered to likely present beneath the RTD at the site, this is considered to hydraulically separate groundwater within the RTD from bedrock aquifers of the Lambeth Group, Thanet Sand Formation and Chalk.

2.6.3. Source Protection Zones

The site lies within an Outer Catchment (Zone 2) Source Protection Zone (SPZ). The Environment Agency [9] defines SPZs as “zones which show the level of risk to the source from contamination SPZ 2 as having “[a] 400 day travel time of pollutant to source. This has a 250 or 500 metres minimum radius around the source depending on the amount of water taken.” SPZ1’s lies to the north, east and south of the site, a SPZ1 is defined by the Environment Agency as ‘This zone is 50 day travel time of pollutant to source with a 50 metres default minimum radius’. It is currently not known if the SPZ is associated with water with the permeable superficial deposits (RTD) or deeper groundwater of the bedrock deposits (Lambeth Group, Thanet Formation and Chalk). Water wells recorded on BGS online datasets, located in the vicinity of the SPZ centres, are typically associated with Chalk or Lambeth Group aquifers with a number to the east associated with Banbury and Lockwood Reservoirs reported to abstract from the RTD.

2.6.4. In situ Groundwater Parameters

Groundwater sampling records the following in-situ groundwater chemistry parameters: pH, temperature, dissolved oxygen, redox potential and electrical conductivity, these are presented in Appendix B. Measured dissolved oxygen levels were variable and ranged between 1% and 64% indicating both anaerobic (below 10%) and aerobic (above 10%) conditions are present at the site. Where groundwater is impacted by hydrocarbons anaerobic conditions are expected to prevail, however the measured values indicate that where this impact is not present aerobic conditions can be expected. As such the RTD down gradient from the site is assumed to be aerobic.

2.7. Hydrology

The closest surface water feature to the site is the Pymmes Brook, located approximately 30 m to the east of site parallel to the eastern site boundary. The Brook flows from the north-north-east to south-south-west direction. The River Lee Navigation Canal is located 230 m east of the site and the River Lee (River Lee Diversion) is located approximately 250 m east of the site. Other water features include the Banbury Reservoir located approximately 360 m east of the site and the Lockwood Reservoir located approximately 530 m south of the site. The Banbury and Lockwood Reservoirs are part of the Lee Valley Reservoir Chain that provides drinking water to London.

It is understood that the Lee River Reservoir Chain are primarily fed by surface waters, including Pymmes Brook, River Lee Diversion and River Lee Flood Relief Channel.

The section of Pymmes Brook closest to the site had a 'moderate' ecological status in 2019 according to Water Framework Directive assessments [10]

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

It is understood from publicly available reports that Pymmes Brook was channelised in response to the Lee Conservancy Catchment Board Act 1938, with the proposal developed in the late 1950s. The channels incorporate a concrete base typically 9 m wide and side walls which are typically 3.7 m high. Through the reach of the Pymmes Brook, adjacent to the site, the banks comprise of sheet piles with concrete capping. These walls act as flood defences, preventing flood arising from the Brook. In addition, the eastern wall also prevents overland flooding, arising from the Canal, from entering the Pymmes Brook.

The Lee Navigation channel is located approximately 230 m to the east of the site. Water within the channel is assumed to be approximately 8 m AOD [11].

The River Lee (Diversion) is located approximately 250 m to the east of the site, this is assumed to be approximately 5 m AOD, lower than measured groundwater levels observed at the site [11].

The River Lee Flood Relief Channel is also located 310 m east of the site at its closest point, this channel is a tributary of the River Lee Diversion channel. Water within the channel is assumed to be approximately 8 m AOD to the east of the site.

Pymmes Brook, Lee Navigation channel, River Lee Diversion and River Lee Flood Relief Channel all merge approximately 2 kilometres to the southeast of the site into the River Lee.

2.8. Site Drainage

2.8.1. Current

A surface drain enters the site from Leaside Road crossing the northern boundary in a north-east to south-east orientation, exiting the site at the eastern boundary.

2.8.2. Proposed site drainage

The drainage design has yet to be finalised, as such this assessment will consider the situation where no engineered drainage is implemented and infiltration could occur across the entire site.

2.9. Summary of Visual and Olfactory Evidence of Contamination

A summary of visual and olfactory signs of contamination observed at the site has been presented in Table 2-2 below. These have been grouped by 'historical source' as detailed on Figure 3.

Borehole logs are presented in Appendix A.

Table 2-2– Summary of Visual and Olfactory Signs of Contamination

Identified onsite Historical Land uses (numbers as per Figure 3)	BH ID	Observation
Leaside Engineering Works	BH12-06	Strong 'sickly sweet' odour in Alluvium and RTD, saturated zone. Made Ground not sampled.

Identified onsite Historical Land uses (numbers as per Figure 3)	BH ID	Observation
Unknown Structures 1969 – 1970 (2)	WS12-07	Strong ‘sickly sweet’ odour in Made Ground and ‘sticky sweet’ odour and Hydrocarbon odour in Alluvium, unsaturated and saturated zone.
Unknown Structures 1969-1991 (5)	WS12-08	No visual or olfactory indication of contamination in log.
	BH12-05	No visual or olfactory indication of contamination in log.
Leeside Engineering works- Unknown structures 1969-1970 (6)	BH12-04	Strong hydrocarbon odour and tar in Made Ground above groundwater level. Hydrocarbon within fissures of Alluvium.
	WS12-05	Slight hydrocarbon odour in unsaturated Made Ground.
	WS12-06	Hydrocarbon odour at water table, hydrocarbon in fissures in Alluvium.
	BH11	Strong hydrocarbon odour at water table in Made Ground, moderate hydrocarbon odour in Alluvium, oil sheen on gravels at base of RTD.
	BH23-04	Strong hydrocarbon odour and staining in Made Ground.
Pond 1960-1974 (10)	WS12-04	No visual or olfactory indication of contamination in log.
	WS12-06	Hydrocarbon odour at water table, hydrocarbon in fissures in Alluvium.
	WS12-03	No visual or olfactory indication of contamination in log.
	BH12-03	Hydrocarbon odour at base of Made Ground and within Alluvium.
	BH12	Strong hydrocarbon odour at base of Made Ground, within Alluvium and odour and sheen in RTD.
Pond 1950-1960 (9)	WS12-02	Strong diesel odour in Made Ground, Alluvium and RTD
	WS12-01	Oil Staining and strong hydrocarbon odour in Alluvium,
	BH12-02D	Hydrocarbon odour and tar in Made Ground, Alluvium and RTD.
	BH12-01	Strong hydrocarbon Odour and Staining in Made Ground
Edge of site	BH23-03	Hydrocarbon odour and staining in Made Ground (EOH above water table)
	BH23-05	Hydrocarbon Odour, staining and visual free product in Made Ground (EOH above water table)

2.10. Observations of NAPL

A summary of observations of measurable non-aqueous phase liquid (NAPL) is presented in Table 2-3, while observations of free product in the water column are noted in Table 2-4. It should be noted that observations from BH12-02D from 2023 have been excluded from this assessment as the depth to base of the borehole measured in 2023 is recorded as above the response zone. This indicates a potential measurement error or that that this borehole is compromised, and data collected in 2023 may also be incorrect.

Figure 9 shows the potential extent of the dense non-aqueous phase liquid (DNAPL) at the site.

Table 2-3 – NAPL Measurements

Borehole	NAPL Measurement	Date	Observation
BH11	0.69 m DNAPL	10/05/2023	-

Borehole	NAPL Measurement	Date	Observation
	0.45 m DNAPL	04/07/2023	-
BH12-01	1.5 m DNAPL	01/03/2013	-
	0.1 m DNAPL	14/02/2023	Difficult to get reading. Globules of NAPL noted through water column.

(-) No commentary provided.

Table 2-4 – Observations of Potential NAPL

Borehole	Date	Observation
BH12-01	08/06/2023	Droplets and oily sheen in sample
BH12-03	10/05/2023	Sheen on water observed.
WS12-01	01/03/2013	Trace product noted on end of interface probe
WS12-02	07/06/2023	Free product noted and oil sheen on water

2.11. Regulatory Correspondence

A meeting was held between the EA and AtkinsRéalis in December 2023 and the minutes prepared by the EA and AtkinsRéalis subsequent to the meeting are included in Appendix G. The pertinent points that have been included in this assessment are included below:

- The Pymmes Brook and Secondary A Aquifer associated with the RTD beneath the site is a receptor. The RTD has been included as a receptor downgradient from the site and justification has been provided herein;
- Publicly available information from the Meridian Water site to the north has been incorporated into the assessment, specifically the hydraulic conductivity;
- The potential that ammonium is present in groundwater beneath the site as a result of off-site historical industrial activities has been assessed; and
- The impact of the potential removal of the hardstanding slab across the site as part of the demolition works may have on infiltration has been included in the DQRA.

2.12. Hydrogeological Conceptual Model

2.12.1. Baseline

A hydrogeological conceptual model has been developed, this understanding is presented in Figures 6 and 7. The following has been conceptualised from available data for the site:

- Based on groundwater levels observed in the RTD beneath the site and an understanding of the greater area, it is considered likely that groundwater within the RTD is flowing in a generally southern direction. Based on observed groundwater (RTD) and surface water levels (as shown in Figure 7) there is the potential that Pymmes Brook is hydraulically connected to groundwater beneath the site. It is also considered likely that the interaction between surface water and groundwater beneath the site changes throughout the reach along the site boundary, with groundwater levels observed at the site higher than the measured level in the Brook in the north of the site (localised flow away from the brook) and groundwater levels observed lower than the Brook in the south of the site (localised flow towards the brook). It is acknowledged that the engineering structures and canalisation of Pymmes Brook will likely restrict interactions between groundwater and surface water.
- It is also considered likely that the RTD beneath the site is hydraulically connected to the River Lee and River Lee diversion. The River Lee Navigation Channel and Reservoir system are considered likely hydraulically disconnected from groundwater due to their engineering. It is noted that the Reservoir system is partially feed from water from the River Lee and River Lee division (i.e. local surface water).

- The Alluvium (where present) appears to be hydraulically separating water within the Made Ground and groundwater within the RTD. The Alluvium is considered to be limiting vertical contamination migration to the RTD from the Made Ground, where present. Where the Alluvium is not present (in the south of the site) it's expected that the RTD and Made Ground are in hydraulic continuity.
- Groundwater within the Made Ground is considered to represent a source and not a controlled waters receptor. Based on the understanding that Pymmes Brook is culverted and observed groundwater levels in the Made Ground (approximately 8.8 m AOD) and water levels in the Brook (approximately 7.5 m AOD) it is not thought that the Made Ground is directly discharging into the Brook as shows in Figure 7. Based on the heterogeneity of the Made Ground and observed water levels within the unit any flow within the unit is likely to be irregular.
- Due to the historical land use in the greater area (gas works and other industry) groundwater quality in the RTD is considered to be poor in the wider area around the site.
- The site lies within an SPZ2 with a number of SPZ1s to the north, east and south. It is currently not known what unit the abstractions driving the SPZ1s are abstraction from, but it is thought to be a combination of both Chalk and RTD based on information obtained from Geoindex viewer (2023). According to the BGS water well database all sites registered as RTD within the vicinity of the site (1 km) are on the eastern side of the Pymmes Brook and the River Lee (Diversion and Flood Defence Channel) as such it is considered likely that these abstractions are hydraulically separated from the site by the surface water features.
- Due to the observed DO levels beneath the site and on adjacent sites it is considered likely that groundwater within the RTD is considered to be aerobic beyond the site boundary.
- Based on the thickness of the London Clay beneath the site groundwater within the Lambeth Group, Thanet Sands and the Chalk, are thought to be hydraulically isolated from the site and as such are not considered controlled water receptors.
- The site is covered in hard standing/buildings and as such limited infiltration is thought to occur across the site.
- Based on the hydrogeological understanding at the site it is considered likely that groundwater within the RTD beneath the site discharges to surface water receptors (Pymmes Brook / River Lee including the River Lee Diversion and Flood Defence Channel). As these surface waters feed the Lee Valley Reservoir System both Fresh Water Environmental Quality standards and Drinking Water Standards are considered appropriate generic criteria to protect both the environment and human health.

2.12.2. Demolition, Construction and Operation

Based on an understanding of the works likely to occur during demolition, construction and operation and the limited depth of earthworks (above water table) including no piling works, it is considered unlikely that, other than an increase in infiltration, the hydrogeological conceptual model will not be altered through the course of development.

The impact that an increase in infiltration has on risks to controlled waters and how these risks differ from the baseline will be considered in Section 5 Detailed Quantitative Risk Assessments.

3. Conceptual Site Model

3.1. Introduction

Land contamination is assessed through the identification of Potential Contaminant Linkages (PCLs) as set out in the Environment Agency 2020, Land Contamination Risk Management Framework (LCRM) [3]. The assessment involves the development of a conceptual site model (CSM) which describes the relationship between on and off-site potential sources of contamination (and contaminants), potential receptors to such contamination and anticipated pathways between the two. Where all three (source-pathway-receptor linkage) are present or considered to be present, they are described as a PCL which can be subject to the risk assessment process.

Within the CSM, risks have been assessed in accordance with the methodology and classification system set out in CIRIA C552 Contaminated Land Risk Assessment, A Guide to Good Practice [12].

The CSM presented in Sections 3.2 to 3.5 has been produced based on site setting data presented in this report.

The CSM considers both the site's current use as non-operational land comprising commercial tenanted properties and the proposed future use as an operational electricity substation.

This CSM only considers risks to controlled waters from on-site sources, off-site sources are not considered within this CSM.

3.2. Sources

The potential sources of contamination at the site are as summarised below:

- Site-wide potentially contaminated Made Ground. Potentially impacted with hydrocarbons (including free phase) and/or with unknown chemicals associated with past and current industrial use of the site.
- Potentially contaminated groundwater within the RTD.
- Free phase, including identified dense non-aqueous phase liquid (DNAPL) at the base of the RTD.

3.3. Receptors

The following potential controlled waters receptors have been identified:

- R1 – surface waters as discussed in Section 2.5.
- R2 – groundwater within the RTD down hydraulic gradient from the site.

The groundwater within the RTD beneath the site is considered to represent a pathway for water movement to Pymmes Brook. Due to the historical land use in the greater area (gas works and other industry) background groundwater quality in the RTD is considered to be poor. As such as part of this assessment the RTD beneath the site is not a receptor in itself.

Groundwater within the deep bedrock aquifers is not considered a receptor due to a sufficient thickness of London Clay beneath the site between the superficial and deeper aquifers.

3.4. Pathways

3.4.1. Controlled Waters

Potential pathways to receptors include the following:

- Leaching/dissolution from contaminated soil followed by lateral migration in groundwater;
- Migration of contamination already present within groundwater;
- Leaching / dissolution of NAPL followed by migration in groundwater; and
- NAPL migration and discharge to surface water.

As the site is currently covered in hardstanding which will be replaced with crushed concrete during remediation, construction and operation phases, the pathways are considered the same through all phases of works.

3.5. Potential Contaminant Linkages (PCLs)

Table 3-1 presents the preliminary CSM and PCLs which were identified as representative of a potentially unacceptable risk to Controlled Waters receptors during all phases of the development.

Table 3-1 – CSM summarising PCLs for current and future use as an electricity substation

Source and Area/Structure	Critical Receptors and Scenarios	Pathway	Potential Consequence of Complete Contaminant Linkage	Likelihood of Complete Contaminant Linkage	Risk
- Site-wide potentially contaminated Made Ground. Potentially impacted with hydrocarbons (including free phase) and/or with unknown chemicals associated with past and current industrial use of the site. - Potentially contaminated groundwater within the RTD. - Free phase, including identified dense non-aqueous phase liquid (DNAPL) at the base of the RTD.	Surface water and down gradient groundwater	Leaching/dissolution from contaminated soil followed by migration in groundwater	Moderate	Unlikely (baseline) Likely (Remediation, construction, and operation)	Unlikely Risk Moderate Risk
		Migration of contamination already present within groundwater	Moderate	Likely	Moderate Risk
		Leaching / dissolution of NAPL followed by migration in groundwater	Moderate	Likely	Moderate Risk
		NAPL migration and discharge to surface water	Moderate	Likely	Moderate Risk

4. Generic Quantitative Risk Assessment

4.1. Introduction

The GQRA involves comparing contaminant concentrations observed at the site with appropriate generic assessment criteria (GACs). The GQRA forms Tier 2 of the tiered approach to assessing risks from land contamination as set out in LCRM [3]. The controlled waters GQRA has been designed to assess the potential risks posed to the controlled waters receptors identified in the preliminary CSM, presented in Section 3.

The assessment has been undertaken using soil-derived leachate, groundwater and surface water data collected during from the site. Based on the groundwater monitoring data from the superficial deposits, collected in 2013 and 2023. Data from 2013 have been used in the assessment. Inherent limitations associated with the age of the data are acknowledged and discussed where pertinent. Laboratory results used in this assessment are presented in Appendix C1.

4.2. Selection of Controlled Waters Generic Assessment Criteria

The screening criteria for controlled waters assessment are dependent on the nature of the principal receptors identified.

The soil-leachate and groundwater has been screened against the following:

- UK Drinking Water Standards (DWS) [13]; and
- Environmental Quality Standards (EQS) [14].

Where applicable UK standards are not available, either non-statutory guideline where relevant to the receptor, have been utilised.

The bioavailability of certain metals (copper, lead, nickel, zinc) varies depending on the hydrochemical characteristics of the receiving surface water body. Published EQS values are unadjusted values which are highly conservative. Site-specific Predicted No Effect Concentrations (PNEC) values have been derived using the WFD-UK rivers and lakes metal bioavailability assessment tool (mBAT) [15], to define site-specific EQS that accounts for the bioavailability for each relevant metal within the receiving water body. The dissolved organic carbon and pH values used in the assessment were obtained from Environment Agency monitoring data collected from Pymmes Brook in 2014 approximately 3 km downgradient from the site (TH-PLER0117). The calcium concentration use was reported within a sample collected from the Salmon Brook (TH-PLER0110), a tributary to Pymmes Brook sampled 1.3 km north of the site. The calcium value is considered a good approximation of calcium values likely to be present within Pymmes Brook as both Pymmes Brook and Salmon Brook have similar base geology and land uses within their catchments. The mBAT sheets are presented in Appendix C2.

4.3. Screening

Screening has been carried out on all available data from the MG and RTD within the site, this includes data collected in 2013 and 2023 and presented in Appendix C3. Data from BH12-02D from 2023 has been excluded as the noted depth to base is higher than the screened interval and the survey plots the well in a different location to co-ordinates from 2013, as such the data is deemed not representative of RTD groundwater conditions. Additionally, BH23-03 and BH23-05 are screened above observed groundwater levels in the Made Ground across the site, as such water samples collected from these boreholes is not considered representative of conditions within the Made Ground but water that has collected within the well.

4.3.1. Groundwater

Table 4-1 – Summary of DWS GQRA exceedances within groundwater data

Parameter	Unit	DWS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (location and units)
Inorganics						

Parameter	Unit	DWS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (location and units)
pH	pH units	6.5-9.5	24	2.46	7.60	3 (WS12-07 (2) MG BH12-02D RTD)
Ammoniacal Nitrogen as NH ₄	mg/l	0.5	54	0.054	110	52 MG and RTD
Total Cyanide	mg/l	0.05	54	0.01	2.0	41 MG and RTD
Chloride	mg/l	250	54	19	4,130	21 MG and RTD
Sulphate	mg/l	250	54	<1	6,960	40 MG and RTD

Metals

Dissolved Arsenic	mg/l	0.01	54	0.0003	0.58	19 MG: WS12-01, WS12-02, WS12-03, WS12-07, BH23-04 RTD: BH11, BH12, BH12-05
Dissolved Cadmium	mg/l	0.005	54	0.00003	0.23	2 MG: WS12-07
Total Dissolved Chromium	mg/l	0.05	54	0.0002	0.53	2 MG: WS12-07
Dissolved Lead	mg/l	0.01	54	<0.0004	0.33	13 MG: WS12-02, WS12-03, WS12-06, WS12-07, RTD: BH11, BH12,
Dissolved Nickel	mg/l	0.02	54	0.0005	0.66	12 MG: WS12-07, WS12-08, BH23-04 RTD: BH11, BH12-03
Dissolved Selenium	mg/l	0.01	54	<0.0005	0.027	4 MG: WS12-07 BH23-04
Dissolved Zinc	mg/l	3	54	0.0015	7.6	2 MG: WS12-07

Organics

Benzo(a)pyrene	mg/l	0.00001	55	<0.000016	0.065	4 RTD: BH11: BH12-03, BH12-04, BH1204
Benzene	mg/l	0.001	55	<0.0005	180	44 MG: and RTD
1,2-Dichloropropane	mg/l	0.04	23	<0.002	0.058	1 RTD: BH11
Toluene	mg/l	0.7	55	<0.0005	29	27 MG: WS12-01, WS12-02, WS12-06, WS12-07, WS12-8, BH23-04

Parameter	Unit	DWS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (location and units)
						RTD: BH11, BH12, BH12-01, BH12-02D
Ethylbenzene	mg/l	0.3	55	<0.0005	4.5	16 MG: WS12-01, WS12-02, WS12-07 RTD: BH11, BH12-01, BH12-04
Styrene	mg/l	0.02	24	<0.002	2.1	6 MG: WS12-01, WS12-02 RTD: BH11m BH12, BH12-02D
Phenol	mg/l	0.05	56	<0.0005	12	31 MG: WS12-01, WS12-02, WS12-06, WS12-07, BH12-04 RTD: BH11, BH12, BH12-01, BH12-02D, BH12-03, BH12-04

Table 4-2 – Summary of EQS GQRA exceedances within groundwater data

Parameter	Unit	EQS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (location and units)
Inorganics						
Ammoniacal Nitrogen as NH ₄	mg/l	0.26	54	0.054	110	52 MG and RTD
Free Cyanide	mg/l	0.001	54	0.005	0.088	6 MG: WS12-01, WS12-02, WS12-07 RTD: BH12-02D, BH12-06
Chloride	mg/l	250	54	19	4100	21 MG: WS12-01, WS12-03, WS12-07, WS12-08 RTD: BH11, BH12, BH12-02D, BH12-04, BH12-05,
Sulphate	mg/l	400	54	<1	6960	18, MG: WS12-01, WS12-03, WS12-06, WS12-07, WS12-08, WS12-03, BH12-04 RTD: BH12-03
Metals						
Dissolved Arsenic	mg/l	0.05	54	0.0003	0.58	9 MG: WS12-01, WS12-07

Parameter	Unit	EQS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (location and units)
Dissolved Cadmium	mg/l	0.00015	54	0.00003	0.23	7 MG: WS12-01, WS12-06, WS12-07, RTD: BH11, BH12,
Dissolved Copper	mg/l	0.03449	54	<0.0005	0.25	2 MG: WS12-07
Dissolved Lead	mg/l	0.00888	54	<0.0004	0.33	11 MG: WS12-02, WS12-03, WS12-06, WS12-07, RTD: BH11, BH12
Dissolved Nickel	mg/l	0.01998	54	0.0005	0.66	12 MG: WS12-07, WS12-08, BH23-04 RTD: BH11, BH12-03
Dissolved Zinc	mg/l	0.03511	54	0.0015	7.6	11 MG: WS12-06, WS12-07, WS12-08, RTD: BH11, BH12, BH12-02D
Organics						
Naphthalene	mg/l	0.002	55	<0.000014	98	42 MG and RTD
Anthracene	mg/l	0.0001	55	<0.000013	5.5	30 MG: WS12-01, WS12-02, WS12-03, WS12-06, WS12-07, WS12-08, BH23-04 RTD: BH11, BH12, BH12-01, BH12-02D, BH12-04, BH-05, BH12-06
Fluoranthene	mg/l	0.0000063	55	<0.000012	4.9	28 MG: WS12-01, WS12-02, WS12-03, WS12-06, WS12-07, BH23-04 RTD: BH11, BH12, BH12-03, BH12-04, BH12-05, BH12-06 MG/RTD: BH12-01
Benzo(a)pyrene	mg/l	0.00000017	55	<0.000016	0.066	4 RTD: BH11, BH12-03, BH12-04

Parameter	Unit	EQS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (location and units)
Benzene	mg/l	0.01	55	<0.0005	180	36 MG: WS12-01, WS12-02, WS12-03, WS12-06, WS12-07, WS12-08, BH23-04 RTD: BH11, BH12, BH12-02D, BH12-04, BH12-05 MG/RTD: BH12-01
Toluene	mg/l	0.074	55	<0.0005	29	29 MG: WS12-01, WS12-02, RTD: BH10,
Styrene	mg/l	0.05	23	<0.002	2.08	6 MG: WS12-02, WS12-02 RTD: BH11, BH12, BH12-02D
1,4-Dichlorobenzene	mg/l	0.02	29	<0.003	0.029	1 RTD: BH12
1,2-Dichlorobenzene	mg/l	0.02	29	<0.003	0.021	1 RTD: BH12
Phenol	mg/l	0.0077	56	<0.0005	12	39 MG and RTD

4.3.1.1. Groundwater Screening Discussion

Groundwater exceedances of DWS and EQS have been discussed below:

All wells which were present in 2013 were sampled in 2023 except for BH12-02D, where NAPL was previously recorded. This has been taken into account in the discussion below.

Inorganics

- pH was analysed in 2013 in the laboratory, one monitoring well reported low pH values within the Made Ground (WS12-07) and one in the RTD (BH12-02D) outside appropriate pH ranges (both DWS and EQS). Due to short holding times, laboratory analysed pH values are not always reliable, field measurements from 2023 reported values between 1 and 7 at the site and adjoining sites which were monitored. It is acknowledged that pH values of 1 are highly unlikely to be present, however, it is considered that pH is highly variable at the site with levels being reported higher than quality standards. It is considered likely that the observed variability in pH is a result of both naturally conditions (presence of peat in the Alluvium is known to decrease pH levels). Additionally, pH is quickly buffered in the environment via number of complex reactions. As such pH is not considered further in this assessment as it is not considered likely to pose a risk to the wider environment down gradient.
- Ammonium concentrations exceeded the DWS and EQS within the majority of samples, with the highest observed concentrations recorded in Made Ground monitoring wells WS12-01, BH23-04 and RTD monitoring well BH11. The logs for these boreholes all indicated olfactory and visual signs of hydrocarbon contamination with BH11 reporting a thickness of DNAPL at the base of the RTD. Based on the historical land use at this site it is considered likely that ammonium present within these wells and across the site is a consequence of degradation of organics and not from discrete ammonium sources.
- Total cyanide again exceeded the DWS within the majority of samples collected at the site, with the highest observed values (above 0.5 mg/l) recorded within the Made Ground at WS12-01, WS12-06, WS12-07 located at the southern end, middle and top respectively in 2013 and in BH23-04 and BH23-05 located on the eastern boundary in 2023.

- No exceedance of EQS were reported from samples from the Made Ground or RTD for free cyanide in 2023, where exceedances were reported in 2013 these were below LOD in 2023. As such free cyanide is not considered to pose a current risk to surface water receptors and is not considered further.
- Chloride exceedances of the DWS and EWS were reported within both the Made Ground and RTD, with the highest concentrations (above 500) observed in Made Ground wells WS12-01, WS12-07, WS12-08 in 2013 and RTD well BH12 in 2023. The presence of chloride is considered likely due to the historical use of the site as a bus garage and the likely use of salt in the winter months or offsite sources such as leaking sewers.
- Sulphate exceedances of the DWS and EQS were observed within both the Made Ground and RTD, with all the highest exceedances (above 500) observed in the Made Ground across the site within 2013 and 2023. Due to the site history, the presence of sulphate is considered a by-product of the breakdown of organic contamination and is not considered a discrete source itself. As such sulphate will not be considered further.

Metals

- No exceedances of the DWS or EQS for arsenic, cadmium or chromium total were observed in 2023 within the RTD, exceedances were observed within the Made Ground in 2023 for arsenic and cadmium indicating that there is a potential source of arsenic and cadmium at the site but that this is not currently impacting controlled waters receptors.
- Exceedances of lead DWS were reported within RTD (BH11) in the centre of the site in 2013 and 2023. Exceedances of both DWS and EQS for lead were reported in the Made Ground within WS12-07 in the north in 2023. In addition, lead was identified in WS12-02, WS12-03 and WS12-06 (exceeding both DWS and EQS) on one off occasions in 2013.
- No exceedances of DWS were reported of nickel, selenium and zinc in 2023 within RTD. A source of nickel and selenium, however, is considered likely to be present within the Made Ground however this does not appear to be impacting current groundwater quality.
- Copper exceeded the EQS within the Made Ground (WS12-07), no exceedances were reported within the RTD and as such is not considered to be impacting controlled waters.
- Nickel exceeded the EQS within Made Ground (WS12-07 and WS12-08, BH23-04) in 2013 and 2023, and the RTD in BH11 in 2013. As there are no current exceedances of nickel in the RTD, nickel is considered not to be posing a risk to controlled waters receptors.
- Zinc concentrations exceeded the EQS within Made Ground (WS12-07) in 2023 indicating a current source. Exceedances of EQS in the RTD are however sporadic and as such the impact in the Made Ground is not considered to be impacting current groundwater quality to an unacceptable level.

Organics

- Benzo(a)pyrene reported exceedances of DWS and EQS in RTD groundwater samples BH12-03, BH12-04 and BH11 in 2013. No exceedances were reported in 2023. BH12-04 and BH11 were sampled in 2023 indicating that the risk from benzo(a)pyrene in these areas has reduced. There is the potential that there is still dissolved phased benzo(a)pyrene in the centre of the site (BH12-03) which poses a risk to controlled waters receptors.
- Anthracene and fluoranthene exceeded the EQS in 2023 within the Made Ground and RTD, indicating that there is a source of these determinands that is impacting groundwater quality at the site.
- Elevated benzene concentrations in excess of DWS and EQS have been reported within both the RTD and Made Ground across the site. Generally observed concentrations were higher in 2013 than they were in the 2023 monitoring indicating conditions at the site are improving over time. Elevated concentrations in excess of 20 mg/l were reported in the Made Ground within WS12-07, WS12-02, WS12-01 and BH23-04 and Made Ground/RTD well BH12-01.
- No exceedances of screening criteria were reported for toluene in the RTD during the 2023 monitoring, exceedances persist within the Made Ground indicating that the Made Ground source is not impacting groundwater quality at the site.
- Ethylbenzene reported exceedances of the DWS in RTD groundwater from BH11 in 2023, Made ground source persists however reported concentrations have reduced since 2013.

- Phenol exceeded the DWS and EQS in both the Made Ground and RTD in 2013 and 2023. The majority of the highest observed concentrations (above 1.5 mg/l) were reported in 2023 within both the Made Ground and RTD.

4.3.2. Leachate

Due to the limited unsaturated zone at the site, only five leachate samples were considered to be suitable for screening. These have been screened for completeness but have not been used to characterise the risk posed to controlled waters from the unsaturated zone due to the low number of samples.

Due to the limited unsaturated zone, it is considered likely that any associated impact is in equilibrium with groundwater and therefore, assessment of groundwater data is considered to be appropriate. Leachate results are fully considered in the CWDQRA.

Table 4-3 - Summary of DWS GQRA exceedances within Leachate data

Parameter	Unit	DWS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (Unit)
Ammoniacal Nitrogen as NH ₄	mg/l	0.5	5	<0.05	2.4	2 MG
Total Cyanide	mg/l	0.05	5	<0.05	0.15	2 MG & ALV
Dissolved Arsenic	mg/l	0.01	5	<0.0009	0.08	3 MG
Benzo(a)pyrene	mg/l	0.00001	5	<0.000016	0.00217	1 MG
Benzene	mg/l	0.001	5	<0.001	1.9	2 MG
Phenol	mg/l	0.05	5	<0.0005	0.13	2 MG

Table 4-3 - Summary of EQS GQRA exceedances within Leachate data

Parameter	Unit	EQS	No. of Samples	Min. Value	Max. Value	No. of Exceedances (Unit)
Ammoniacal Nitrogen as NH ₄	mg/l	0.26	5	<0.05	2.4	2 MG
Dissolved Arsenic	mg/l	0.05	5	<0.0009	0.08	1 MG
Dissolved Copper	mg/l	0.001	5	0.00054	0.005	3 MG
Dissolved Lead	mg/l	0.0012	5	<0.0004	0.0042	2 MG
Dissolved Nickel	mg/l	0.004	5	<0.0002	0.0079	1 MG
Dissolved Zinc	mg/l	0.014	5	0.002	0.022	3 MG
Naphthalene	mg/l	0.002	5	<0.000014	0.077	1 MG
Anthracene	mg/l	0.0001	5	<0.000013	0.00029	1 MG
Fluoranthene	mg/l	0.0000063	5	<0.000012	0.013	2 MG
Benzo(a)pyrene	mg/l	0.00000017	5	<0.000016	0.00217	1 MG
Benzene	mg/l	0.01	5	<0.001	1.9	1 MG
Toluene	mg/l	0.074	5	<0.001	0.19	1 MG
Phenol	mg/l	0.0077	5	<0.0005	0.13	2 MG

4.4. Surface water impacts

Screening of groundwater against the GAC values indicate that a large proportion of determinands potentially pose a risk to Pymmes Brook. Sampling of Pymmes Brook has been undertaken in 2023 at locations up and down stream of the site (named SW1 and SW2 respectively) as per Figure 5. Concentrations of parameters which have been identified at concentrations deemed to pose a potential risk to controlled waters within the groundwater screening have been reviewed and are presented in Table 4-2 below.

Table 4-2 - Surface Water Recorded Concentrations

Parameter	Min	Max	SW1	SW2	SW1	SW2	SW1	SW2
			09/05/23	09/05/23	06/06/23	06/06/23	05/07/23	05/07/23
Ammonium	0.16	0.27	0.16	0.17	-	-	0.23	0.27
Total Cyanide*	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride	0.16	83	83	83	<0.050	0.16	67	67
Lead	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Naphthalene	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Anthracene	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Fluoranthene	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Benzo(a)pyrene	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ethylbenzene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phenol	<0.030	<0.030	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

All units are mg/l

* free cyanide reported below detection limit (0.050 mg/L) in all samples.

The observed results from Pymmes Brook indicate that except for ammonium and chloride the contaminants of concern identified exceeding the GAC in groundwater have not been recorded within the Brook. Generally, ammonium and chloride concentrations upstream and downstream of the site are similar with ammonium concentrations marginally increasing between sample points and chloride remaining the same or marginally increasing. Reported concentrations of ammonium are below or at similar concentrations to the GAC and concentration of chloride are below GAC.

Based on the observed data it is considered unlikely that the site is having a detrimental effect on water quality in Pymmes Brook.

4.4.1. Modelled Contaminants of Concern (CoC)

Based on the baseline generic quantitative risk assessment discussed in Section 4 the following contaminants are considered to pose a potential risk to controlled waters and have been subjected to further evaluation within this detailed assessment. The assessment has utilised the lowest Generic Assessment Criteria (GAC), these are presented in Table 5-1.

Table 4-3 - Contaminants of Concern

Parameter	Generic Assessment Criteria (GAC) mg/l	Source of GAC
Ammonium N as NH ₄	0.26	EQS

Parameter	Generic Assessment Criteria (GAC) mg/l	Source of GAC
Total Cyanide	0.05	DWS
Chloride	250	DWS
Lead	0.0088	EQS
Benzene	0.001	DWS
Naphthalene	0.002	EQS
Anthracene	0.00001	EQS
Fluoranthene	0.0000063	EQS
Benzo(a)pyrene	0.00000017	EQS
Ethylbenzene	0.3	WHO
Phenol	0.0077	EQS

5. Detailed Quantitative Risk Assessment

5.1. Introduction

The following quantitative assessment provides soil, soil-derived leachate, and groundwater Site Specific Assessment Criteria (SSAC) to assess baseline conditions and provides a qualitative assessment to support the decision-making process for on-going management or future development of the site.

5.2. Methodology

Risks to controlled waters receptors, based site setting information, the conceptual site model, and the generic quantitative risk assessment have been further assessed through CWDQRA. The CWDQRA has been undertaken in accordance with the Environment Agency's guidance including The Environment Agency's approach to groundwater protection [16] and Remedial Targets Methodology [17].

The assessment has been undertaken using the Environment Agency Remedial Targets Methodology (RTM) Worksheet V3.2, which is an analytical spreadsheet-based tool.

The RTM worksheet utilises a range of contaminant transport and hydrogeological equations to model contaminant transport from a defined source (in soil, soil-leachate or groundwater) to a defined compliance point to calculate concentrations of soil, soil-leachate and groundwater that will not result in an exceedance of the relevant water quality standard at the compliance point. The output of the model can then be used as SSAC and compared to measured concentrations recorded at the site.

Investigations indicate that contamination is present within groundwater within the Made Ground, which is hydraulically connected to the RTD (where Alluvium is not present) as well as in the RTD itself and so there is no significant unsaturated zone pathway. Therefore, the RTM model is considered sufficiently appropriate to characterise the site.

A Level 3 (attenuation in the aquifer) assessment, as defined in RTM guidance, has been carried out for soil and groundwater sources for baseline and construction/operational phases. The Level 3 assessment has been used to generate groundwater SSACs as well as a dilution factor which was applied to the screening criteria within a Level 1 (soil zone) and 2 (unsaturated zone and dilution at the water table) assessment which were used to generate soil and soil-leachate SSACs.

Following the Level 3 assessment, a Level 4 assessment was undertaken to understand the potential dilution potential of Pymmes Brook for both baseline and construction/operational phases.

5.3. Compliance Points

Pymmes Brook is located approximately 30 m east of the site, as such a 30 m compliance point has been selected for the assessment.

Groundwater down gradient from the site has been identified as a controlled waters receptor however this is thought to discharge into the Pymmes Brook and other surface waters in the area as such the compliance point and proposed approach detailed in Section 5.4 is considered protective of both surface water and groundwater receptors.

Input parameters used in the assessment and any specific assumptions and limitations are discussed below. All input values are presented in Appendix D.

5.4. Model Set-up

The assessment has been undertaken using justifiable values (based on site-specific or justifiable literature sources) to represent model inputs resulting in a deterministic approach. Where inherent uncertainty in the selection of single values is present, these values have been further considered through sensitivity analysis (Section 6). Two models have been set up to represent baseline and future conditions at the site.

A constant source of contaminant input has been maintained throughout the simulation period for both models, in-line with the Remedial Targets Methodology [17]. This is a precautionary approach as the concentrations of the contaminants on the site have been observed to be declining over time, given there is no evidence of an ongoing continuous source, in addition to the soil sources on site.

5.4.1. Model limitations and assumptions

The following assumptions and limitations were identified and are inherent in the modelling undertaken:

- The site geology and hydrogeology are assumed to be homogenous (where defined in the model), and parameter values and contaminant concentrations used in the CWDQRA are based on chosen values deemed to be most representative of the site;
- No testing has been completed at the site on aquifer properties of the RTD, as such a value of 10 m/d has been used to represent the hydraulic conductivity of the RTD. This value is considered reasonable and is in line with literature values [18].
- Groundwater flow at the site is considered likely to be influenced by a number of factors including surface waters and the presence and absence of the Alluvium, as such an exact flow direction and gradient is difficult to ascertain with site data. It has been assumed that flow is directly towards surface water receptors. A gradient of 0.002 has been inferred using groundwater levels at the site (not influenced by the Made Ground) and surface water levels measured down gradient from the site. This value is considered reasonable for a gravel aquifer with a relatively high hydraulic conductivity.
- An average effective infiltration of 7.04×10^{-4} m/day has been applied to the baseline model. This value has been calculated from effective rainfall mapping [19] and assuming 20% infiltration. An average effective infiltration of 4.93×10^{-3} m/day has been applied to the future model. This value has been calculated from effective rainfall mapping assuming 80% infiltration. It should be noted that with effective compaction of the crushed concrete infiltration will likely be in the realm of 20%.
- An average thickness observed in the logs of the RTD (2.54 m) has been used for the aquifer thickness;
- Where no site-specific data are available, literature sources have been used to develop suitable parameters considered likely to reflect site conditions, as detailed in Section 2;
- Based on the observed visual and olfactory evidence the source area is assumed to be the majority of the site area;
- Based on the hydrogeological conceptual model, groundwater beneath the site is considered likely to be aerobic; and
- One model has been produced using the lowest water quality standard from both DWS and EQS.

5.4.2. Model input parameters

A full list of physical and chemical input parameters is presented in Appendix D1 for baseline and D2 for future.

5.5. Baseline Risk Assessment Results

Calculated SSACs protective of controlled waters at baseline are summarised below in Table 5-1. RTM worksheets are included in Appendix D3 and full screening of the laboratory results is provided in Appendix E1.

In line with RTM [17], where determinands are predicted to take longer than 1,000 years to reach the compliance point this would be unlikely to represent a discernible risk to the receptor and so the values have been greyed out in the table.

Table 5-1 - Summary of derived SSACs for baseline conditions

Parameter	Soil SSAC (mg/kg)	Leachate SSAC (mg/l)	Groundwater SSAC (mg/l)	Groundwater Travel Time (years)
Ammonium	8.82E-01	7.16E-01	2.86E-01	8
Total Cyanide	2.84E+00	2.80E-01	8.58E-02	74
Chloride	7.31E+02	5.93E+02	2.50E+02	8
Lead	5.64E+00	2.09E-02	8.80E-03	1998
Benzene	3.92E-02	5.81E-03	1.76E-03	3
Naphthalene	9.07E-01	1.34E-02	3.83E-03	26
Anthracene	2.07E-02	3.37E-05	1.25E-05	228
Fluoranthene	4.80E-02	2.16E-05	7.94E-06	823
Benzo(a)pyrene	4.55E-03	4.34E-07	1.78E-07	3877

Parameter	Soil SSAC (mg/kg)	Leachate SSAC (mg/l)	Groundwater SSAC (mg/l)	Groundwater Travel Time (years)
Ethylbenzene	1.41E+02	3.25E+00	7.75E-01	17
Phenol	2.18E+00	3.17E-01	4.51E-02	3

5.6. Future Risk Assessment Results

Calculated SSACs protective of controlled waters during future conditions (included in Appendix D) are summarised below in Table 5-2. RTM worksheets are included in Appendix D4.

In line with RTM [17], where determinands are predicted to take longer than 1,000 years to reach the compliance point this would be unlikely to represent a discernible risk to the receptor and so the values have been greyed out in the table.

Table 5-2 - Summary of derived SSACs for baseline conditions

Parameter	Soil SSAC (mg/kg)	Leachate SSAC (mg/l)	Groundwater SSAC (mg/l)	Groundwater Travel Time (years)
Ammonium	6.58E-01	5.34E-01	2.86E-01	8
Total Cyanide	5.30E+01	5.23E+00	8.58E-02	74
Chloride	3.71E+02	3.02E+02	2.50E+02	8
Lead	2.89E+00	1.07E-02	8.80E-03	1998
Benzene	2.23E-02	3.31E-03	1.76E-03	3
Naphthalene	3.43E+01	5.06E-01	3.83E-03	26
Anthracene	1.11E-01	1.80E-04	1.25E-05	228
Fluoranthene	2.57E-02	1.16E-05	7.94E-06	823
Benzo(a)pyrene	2.34E-03	2.23E-07	1.78E-07	3877
Ethylbenzene	5.60E+00	1.30E-01	7.75E-01	17
Phenol	7.39E+04	1.08E+04	4.51E-02	3

5.7. CWDQRA Screening – baseline

Screening of soil, soil-leachate and groundwater against the calculated SSACs is presented in Appendix E. A summary of exceedances is presented in Table 5-3, below.

Table 5-3 - Exceedance Summary

Parameter	Soil Exceedances	Leachate Exceedances	Groundwater Exceedances
Ammonium	11/15	2/4	52/54
Total Cyanide	13/15	0/4	36/54
Chloride	0/15	0/4	21/54
Lead	15/15	0/4	11/54
Benzene	11/15	2/4	44/55
Naphthalene	13/15	1/4	41/55

Parameter	Soil Exceedances	Leachate Exceedances	Groundwater Exceedances
Anthracene	15/15	1/4	30/55
Fluoranthene	15/15	2/4	28/55
Benzo(a)pyrene	15/15	1/2	4/55
Ethylbenzene	1/15	0/4	8/55
Phenol	3/15	0/4	32/56

5.8. Discussion – baseline

Screening of SSAC against available site data indicates a large proportion of exceedances within groundwater for all parameters, further discussion is presented below.

Lead and benzo(a)pyrene are not considered to present an unacceptable risk to receptors due to a travel time greater than 1000 years.

5.8.1. Organics

A high percentage of organic soil and groundwater exceedances have been reported for the site. Given the lithologies at the site and the conservative analysis of the flow path, it is considered likely that soil exceedances are being over reported. Additionally, most of the soils data used in the assessment were obtained in 2013. Inherent limitations associated with the age of the data may be present. For example, organic compounds may have leached and / or degraded in the soil and as such, concentrations across the site may be lower in 2024.

The organic exceedances and potential sources are discussed below:

- Generally observed groundwater benzene concentrations have decreased by an order of magnitude or more within both the RTD and Made Ground between samples obtained in 2013 and 2023 indicating a declining source and lower risk to controlled waters receptors. Reported concentrations in BH12-01 were five orders of magnitude higher than the calculated SSAC. Observed concentrations within BH12-04 within the RTD and WS12-01 and WS12-07 within the Made Ground reported concentrations the same order of magnitude in 2013 and 2023 indicating that there is potentially an ongoing source of benzene in these locations. BH12-01, BH12-04 and WS12-01 are located where NAPL is suspected both BH12-01 and BH12-04 reported high benzene concentrations within unsaturated soil samples indicating a potential source. WS12-07 reported a 'strong sickly sweet' odour within the Made Ground and Alluvium, no corresponding unsaturated soil samples are available for this location. It is suspected that there may be a source in this location associated with the historical land use as the Leaside Engineering Works. In all other locations benzene concentrations have reported a decrease of between 1 to 3 orders of magnitude, it is considered likely that in these locations/areas the risk to controlled waters is considered low.
- Where wells were sampled in 2013 and 2023 naphthalene groundwater concentrations decreased in all instances. One exceedance of 98 mg/l was reported within the RTD within BH12-01 in 2023; however, only one sample has been collected from this well due to the presence of DNAPL. The DNAPL was sampled and reported as Coal Tar. Based on the reported exceedance and high observed concentration there is potentially a localised legacy naphthalene source in the RTD in the vicinity of BH12-01. The relatively low exceedances reported in the Made Ground and remaining RTD groundwater samples are not considered to represent a consistent source. Based on analysis of groundwater results (localised source in the RTD) and corresponding risk, it is considered that the reported naphthalene soil exceedances do not represent a risk to controlled waters receptors.
- The majority of anthracene and fluoranthene groundwater exceedances were reported within the Made Ground in the 2013 and 2023 data and in the RTD in the 2013 data. Exceedances reported of anthracene were reported in the RTD in 2023 in BH12-01 and BH12-04. No exceedances of fluoranthene were reported in the RTD in 2023. The reported anthracene and fluoranthene concentrations within BH12-01 are four and six orders of magnitude higher than the calculated SSAC and these are considered to pose a risk to controlled waters receptors. It is considered likely that the Coal Tar in this location is the source of the reported concentrations of PAH and not the Made Ground. In 2023, BH12-04 has reported exceedances of anthracene in two out of three samples collected, and the log for BH12-04 noted hydrocarbon impact in the Made Ground and Alluvium. The sporadic reported exceedances of anthracene in BH12-04 are marginally above the calculated SSAC with the recorded concentrations in May 2023 reported below detection; as

such, these are not considered to pose an unacceptable risk to controlled waters receptors. Groundwater concentration of anthracene and fluoranthene were sporadically reported in Made Ground monitoring wells in 2023 in excess of the calculated SSAC. Based on the reported groundwater results it is considered unlikely that the sporadic exceedances reported in the Made Ground (both groundwater and soil) are impacting groundwater quality in the RTD and as such these are not considered to be posing a risk to controlled waters receptors.

- A groundwater exceedance of ethylbenzene was reported in the RTD borehole BH12-01 in 2023. The exceedances reported in BH12-01 (only sampled once) was recorded at two orders of magnitude above the calculated SSAC. The Made Ground groundwater exceedances were reported in WS12-02 and WS12-07 in 2023 but these exceedances were sporadic in WS12-02 and WS12-07. The reported exceedances (two out of four) in WS12-02 were in the same order of magnitude as BH12-01. There are no unsaturated soil samples for WS12-02 or WS12-07 to assess the presence of a soil source in this area, the unsaturated soil sample from WS12-01 reported below the calculated SSAC indicating no unsaturated source. It is considered unlikely that the reported inconsistent exceedances in Made Ground groundwater samples of ethylbenzene within monitoring wells WS12-02 and WS12-07 constitute a risk to controlled waters receptors.

5.8.2. Inorganics

- Ammonium - a large proportion of the soil (67%), soil-leachate (50%) and groundwater (95%) samples exceeded the ammonium SSAC. The leachability of ammonium from the soil to liquid phase is dependent on the soil properties, as such a comparison of the potential leachability of ammonium at the site has been completed.

A comparison of soil and soil-leachate results from the site for ammonium indicates that the ratio between soil and soil-leachate results varies between 24 to 104 whereas the calculated ratio between soil and soil-leachate SSAC is 1.23. As such it is considered that the model is overly conservative with respect to ammonium and is over calculating the leachability of ammonium from soil to the liquid phase. Assuming that the soil/soil-leachate ratio is closer to 24 a recalibrated soil SSAC of 30 mg/l is considered reasonable for this site.

Considering a soil SSAC of 30 mg/l, four unsaturated soil samples from three boreholes exceed this value, BH12-01 (2 m bgl), BH12-04 (1 m bgl) and both samples taken from BH23-02 (1.7 m bgl). Based on groundwater levels it is considered likely that the samples from BH12-01 and BH23-02 are at the water table and the observed elevated soil concentrations are potentially from groundwater.

Ammonium impact in groundwater is considered to be site wide and has the potential to impact surface water receptors. Surface water results indicate that ammonium from the site has the potential to impact surface water quality. Two snapshot sampling rounds indicate that ammonium concentrations observed downstream of the site are marginally higher than those recorded at the upstream location, concentration recorded in May were 0.01 mg/l higher downstream and in July 0.04 higher downstream. It is noted that ammonium concentrations were recorded marginally below EQS upstream and marginally above EQS downstream on one occasion. There are numerous off-site sources in proximity to the site.

A review of the historical site use does not imply that ammonium was historically used at the site in large quantities and there is not considered to be a definitive unsaturated soil source at the site. As such it is considered likely that the ammonium observed in groundwater at the site is associated with natural conditions, from the degradation of organic contamination present at the site and/or from offsite activities such as the former gasworks to the north.

- Total Cyanide - total cyanide concentrations exceed the SSAC in more than 50% of groundwater samples from both the RTD and Made Ground reported across the site (except Made Ground monitoring well WS12-08 located in the northwest of the site) in both 2013 and 2023. Reported exceedances in RTD monitoring wells in 2023 were sporadic with no exceedances in BH11 and BH12-06 in 2023, and 2/4 exceedances in BH12, 1/3 in BH12-04 and 2/3 in BH12-05. Reported exceedances in the 2023 data from the Made Ground were more consistent. The location of soil exceedances all reported within wells located within the centre of the site, where hydrocarbon odours were noted to be present within the geological log. No specific visual indication of cyanide/blue billy was noted within the logs at the site or during the intrusive works. It is considered unlikely that the inconsistent RTD exceedances for total cyanide constitute a risk to controlled waters. Additionally, the total cyanide generic assessment criteria used in this assessment is to ensure the safety of drinking water, based on the CSM presented in this report. The use of DWS to protect the Pymmes Brook is a conservative

approach as water within the Pymmes Brook will be further diluted before it reaches the reservoir system located down gradient from the site further reducing the risk that elevated total cyanide poses to controlled waters receptors.

- Chloride – chloride concentrations exceeded the groundwater SSAC in 2023 from one RTD borehole BH12 all other RTD monitoring wells reported concentrations below the SSAC in 2023, as such it's considered unlikely that elevated chloride concentrations observed at the site in the 2023 data pose a current risk to controlled waters. No exceedances were reported for chloride within soil or soil-leachate indicating that there is unlikely to be an unsaturated source onsite.

5.9. CWDQRA Screening – Future

Screening of soil, soil-leachate and groundwater against the calculated future SSACs is presented in Appendix E1. A summary of exceedances of the future scenario and baseline is presented in Table 5-4 below.

Lead and benzo(a)pyrene have been greyed out as they are not considered to pose a risk, where exceedances are the same at baseline to the future scenario these have been greyed out. Where there is a change in exceedances the change in risk has been discussed in Section 5.10.

Table 5-4 - Exceedance Summary baseline vs future

Parameter	Soil exceedances baseline	Soil exceedances future	Leachate exceedances baseline	Leachate exceedances future	Groundwater exceedance baseline	Groundwater Exceedances future
Ammonium	11/15	11/15	2/4	2/4	52/54	52/54
Total Cyanide	13/15	13/15	0/4	1/4	36/54	36/54
Chloride	0/15	0/15	0/4	0/4	21/54	21/54
Lead	15/15	15/15	0/4	0/4	11/54	11/54
Benzene	11/15	12/15	2/4	2/4	44/55	44/55
Naphthalene	13/15	14/15	1/4	1/4	41/55	41/55
Anthracene	15/15	15/15	1/4	1/4	30/55	30/55
Fluoranthene	15/15	15/15	2/4	2/4	28/55	28/55
Benzo(a)pyrene	15/15	15/15	1/2	1/4	4/55	4/55
Ethylbenzene	1/15	1/15	0/4	0/4	8/55	8/55
Phenol	3/15	4/15	0/4	0/4	32/56	32/56

5.10. Discussion – future

The proposed works and increase in infiltration have a limited impact on the risk to controlled waters. Benzene (1), naphthalene (2) and phenol (1) all report an increase in soil exceedances as groundwater impacts are the same at baseline, the risk to controlled waters is considered to be unchanged.

5.11. Climate change

Generally United Kingdom climate predictions (UKCP18) predict climate change in the UK will result in more extreme events such as intense rainfall and storm events resulting in flash floods, hotter drier summers and a higher likelihood of heat waves due to higher temperatures, increased potential evaporation due to higher summer temperatures and consequently a potential increase in drought conditions, milder wetter winters and potentially increased groundwater recharge and rising sea levels [20].

The assessment held herein assesses both current conditions (20%) infiltration of effective rainfall and a future scenario represented by 80% infiltration of effective rainfall. This shows little to no change in the risk to controlled waters from the site. Under future conditions with the chance of both decreased summer and increased winter recharged to groundwater its considered that the risk to controlled waters would be similar if not the same as that presented within this report.

5.12. Summary following Level 3 Assessment

Based on the CWDQRA results, a summary of key sources present on-site that are considered to pose a risk to controlled waters receptors during baseline and future scenarios is presented in Table 5-5 below.

Table 5-5 - Summary of Level 3 Assessment

Source	Contaminant	Discussion
NAPL within the vicinity of BH12-01	Dissolved phase: benzene, naphthalene, anthracene, fluoranthene, ethylbenzene,	The presence of elevated organic contamination within the vicinity of BH12-01 is considered likely due to dissolution from the NAPL present in this area, the exact extent of this is currently unknown, an area of potential impact is presented in Figure 9.
Impact at BH12-04 within both soil and groundwater	Dissolved phase: benzene	Impact noted in both geological log and persistent groundwater exceedances in this location.
Impacted Made Ground and water within the infilled pond in the south of the site (WS12-01)	Dissolved phase benzene	No observed benzene degradation over the last 10 years within Made Ground groundwater, potential local source within the unsaturated zone and / or saturated zone, not delineated. Could be contributing to impact observed in the RTD.
Site wide groundwater	Dissolved phase ammonium	Only viable onsite source identified is the degradation of NAPL.
Unsaturated soil in the vicinity of WS12-07 as detailed in logs	Dissolved phase benzene and ethylbenzene	Impact on controlled waters receptors could be minimal, no RTD samples are available to quantify. No soil samples available to assess potential unsaturated source.

5.13. Level 4 Assessment

A level 4 dilution assessment has been considered in line with RTM [17]. The assessment takes the concentration of determinands within the receiving water body into account. Background concentrations of CoCs within the river have been based on monitored concentrations in the Pymmes Brook in 2023.

With respect to the CoCs modelled in this assessment, only ammonium was identified in the Brook above LOD with ammonium levels measured above EQS on one occasion down gradient from the site. As such, it has conservatively been assumed that the Pymmes Brook does not have capacity to dilute ammonium concentrations. A dilution factor has been calculated and applied to the Level 3 SSACs for the remainder of the determinands deemed to potentially pose a risk to receptors as discussed in Section 5.7.

The dilution factor has been calculated using justifiable values (based on site-specific or justifiable literature sources). Values used to calculate the level 4 dilution factor are the same as that used in the Level 3 assessment with the addition of flow data for the Pymmes Brook. This has been obtained from UK Centre for Ecology and Hydrology River Flow Archive [21]. Approximately 250 m to the north of the site (upstream), a confluence is present where the Salmon Brook and Pymmes Brook merge. The flow data used in this assessment is a combination of measurements from both Brooks upstream of the site.

The Level 4 calculation used to develop the Level 4 dilution factor is presented as Equation 5-1 and the input parameters are presented in Table 5-6.

Equation 5-1 - Level 4 Dilution Equation

$$DF = \frac{Q_C + Q_U}{Q_C}$$

Table 5-6 - Level 4 Input Parameters

Parameter	Value	Comment
Qu - Pymmes Brook Q95 ¹ flow (m ³ /d)	10,109	Q95 measured upstream from the site at Pymmes Brook at Edmonton Silver Street and Salmon Brook at Montague Road. The two Brooks merge upstream from the site.
Qc – Groundwater flow beneath the site k.i.w.Mz	2.6	Calculated
k - Hydraulic Conductivity (m/d)	10	Assumed to represent the RTD, from WorleyParsons 2013 investigation [7].
i - Hydraulic Gradient	0.002	Calculated between site groundwater and Pymmes Brook.
Mz - Mixing Zone Thickness (m)	2.54	Calculated based on site information
w - Width of contaminant zone at right angles to groundwater flow (m)	52	Assumed to be the site width
Dilution Factor	3.83x10 ⁺³	Calculated

¹ Q95 flow is the flow of water in the river that is equalled or exceeded for 95% of the recorded flow at the measurement station.

SSACs developed in the baseline scenario have been recalculated considering the Level 4 dilution factor and presented in Table 5-7 with maximum observed concentrations observed at the site. Additionally, the baseline SSAC for cyanide developed in the future scenario has also been recalculated considering the Level 4 dilution factor.

Table 5-7 - Site Specific Acceptance Criteria with Level 4 Dilution

Parameter	Soil SSAC with Level 4 Dilution Factor (mg/kg)	Maximum Recorded Soil Concentration (mg/kg)	Leachate SSAC with Level 4 Dilution Factor (mg/l)	Maximum Recorded Soil-leachate Concentration (mg/l)	Groundwater SSAC with Level 4 Dilution Factor (mg/l)	Maximum Recorded Groundwater Concentration (mg/l)
Chloride	2.16E+06	3.59E+02	1.75E+06	2.40E+00	7.38E+05	4.13E+03
Total Cyanide	3.41E+03	4.30E+03	3.37E+02	1.50E-01	2.53E+02	1.99E+00
Benzene	1.16E+02	3.61E+02	1.71E+01	1.90E+00	5.18E+00	1.79E+02
Naphthalene	2.68E+03	2.67E+03	3.95E+01	7.70E-02	1.13E+01	9.80E+01
Anthracene	6.12E+01	3.98E+02	9.94E-02	2.90E-04	3.68E-02	5.50E+00
Fluoranthene	1.42E+02	8.60E+02	6.36E-02	1.30E-02	2.34E-02	4.90E+00
Ethylbenzene	4.15E+05	1.45E+02	9.60E+03	1.70E-02	2.29E+03	4.50E+00

Screening of SSACs considering the Level 4 dilution SSACs (Appendix F) indicates that 4 soil samples exceed the SSAC for anthracene, 5 soil samples exceed the SSAC for fluoranthene and 2 soil sample exceed for benzene. The anthracene soil samples were obtained from BH12-01, BH12-02D, BH12-04 and BH23-04. The fluoranthene samples were obtained from BH12-02D, BH12-04, BH12-05, BH23-05 and BH23-04. The benzene sample which exceeds the Level 4 SSAC is also from BH12-04 and BH23-04. BH12-04 and BH23-04 are located in the centre of the site while BH23-05 is located on the northeastern edge of the site. Based on groundwater results, the impacted material noted in BH12-04 and BH23-04 is not influencing groundwater quality in the RTD.

Screening considering the Level 4 groundwater SSAC indicates three exceedances of naphthalene (BH12-01 (2023), BH12-03 (2013) and WS12-07(2013)), three exceedances of anthracene (BH11 (2013), BH12-01(2023) and BH12-03 (2013)), three exceedances of fluoranthene (BH11(2013), BH12-01 (2023) and BH12-03(2013)) and 28 exceedances of benzene. The benzene exceedances were reported in BH11(2013 and 2023),

BH12(2013), BH12-01 (2023), BH12-02D (2013) and BH12-04(2013 and 2023) in the RTD. Exceedances were reported in BH23-04 (2023), WS12-01(2013 and 2023), WS12-02(2013 and 2023), WS12-06(2013), WS12-07 (2013 and 2023) and WS12-08 (2013) within the Made Ground.

As previously discussed, where elevated benzene groundwater concentrations were reported in the 2013 and 2023 data at concentrations an order of magnitude higher than the Level 4 SSAC (BH12-01 in the RTD and WS12-07 in the MG) it is considered likely that there is an ongoing source of contamination present in these areas which poses a risk to controlled waters receptors.

The Level 4 assessment confirms that the sources identified and discussed as part of the Level 3 assessment and summarised in Section 5.12 are considered likely to be posing a risk to controlled waters receptors.

6. Sensitivity Analysis

The model has been set up such that limited attenuation is modelled; this is a function of the aquifer properties, compliance point distance and the fact that the source is in contact with the flow path. This has ultimately resulted in low SSACs for soil, soil-leachate and groundwater. Based on the shape of the site and available data, the aquifer properties beneath the site such as hydraulic gradient and hydraulic permeability are currently uncertain, consequently a conservative interpretation has been taken within the modelling exercise. Analysis of each of these parameters and how they impact the assessment has therefore been presented below.

6.1. Hydraulic Gradient

The hydraulic gradient used in this assessment has been calculated from an observed value in the middle of the site and the down gradient measured surface water reading. As discussed in Section 2.5, the absence of Alluvium in the south of the site has resulted in higher measured groundwater levels in the RTD. Using groundwater levels observed in this area (BH12-01) and the down gradient surface water height, a gradient of 0.006 has been calculated. The impact that this has on the outcomes of the DQRA is minimal with marginally higher SSACs (0.0012 mg/l for benzene) and travel times (0.3 years) which would not impact the outcome of the assessment. As such even with the uncertainty around flow direction and consequently hydraulic gradient, the value used is considered appropriate.

6.2. Hydraulic Conductivity

No hydraulic testing has been completed onsite. Based on lithological description of the RTD at the site, it is considered possible that the actual hydraulic conductivity at the site will be lower than that modelled herein. This would result in an increase in travel time but a decrease in dilution/dispersion within the pathway. The assessment herein has been primarily based on observations of trends within groundwater chemical data and an assessment of likely sources (NAPL / unsaturated zone). It is considered unlikely a lower hydraulic conductivity would impact the outcomes of this assessment.

6.3. Compliance Point

The shortest discharge to the Pymmes Brook has been used in this assessment and it is considered unlikely that groundwater is flowing directly towards the Brook within the RTD. However, increasing the compliance point is not considered to impact the outcomes of this assessment.

A compliance point of 60 m (double that modelled in this assessment) has been considered for benzene. At this distance the travel time doubles from 3 to 6 years but the SSAC for groundwater increases by just 0.005 mg/l. Based on this, extending the compliance point distance by a limited degree does not have impact on the assessment presented herein that would change the conclusions of the modelling.

7. Updated Conceptual Model

Based on the assessment contained herein, the conceptual model has been updated and is presented in Table 7-1.

Table 7-1 - Updated Conceptual Site Model

Source and Area/Structure	Critical Receptors	Pathway	Potential Consequence of Complete Contaminant Linkage	Likelihood of Complete Contaminant Linkage	Risk
Impacted Made Ground (potentially free phase) in the vicinity of BH12-04, BH23-04 BH23-05 and WS12-07	Surface water and down gradient groundwater	Leaching/dissolution from contaminated soil followed by migration in groundwater;	Moderate	Likely	Moderate Risk
		Leaching / dissolution of NAPL followed by migration in groundwater	Moderate	Likely	Moderate Risk
		Soil erosion/surface flooding resulting in discharge of contaminants to surface water	Moderate	Unlikely	Low Risk
Impacted groundwater within the RTD in the vicinity of BH12-01.	Surface water and down gradient groundwater	Migration in groundwater;	Moderate	Likely	Moderate Risk
Ammonium impacted groundwater at the site.	Surface water and down gradient groundwater	Migration in groundwater;	Moderate	Likely	Moderate Risk
Free phase, including identified dense non-aqueous phase liquid (DNAPL) at the base of the RTD at BH12-01 and within the infilled ponds.	Surface water and down gradient groundwater	Leaching / dissolution of NAPL followed by migration in groundwater	Moderate	Likely	Moderate Risk
		NAPL migration and discharge to surface water	Moderate	Likely	Moderate Risk

8. Conclusions and Recommendations

A detailed risk assessment has been completed at the site assessing all available data to quantify the risks to controlled waters from legacy impact at the site. The assessment also considers that the construction and operation phases will have no change to the impact on controlled waters relative to the baseline risk assessed.

Based on groundwater level monitoring, there appears to be two groundwater bodies beneath the site: one in the RTD and one within the Made Ground. Considering groundwater levels observed in the RTD beneath the site and an understanding of the greater area, it is likely that groundwater within the RTD is flowing in a generally southern direction. Based on observed groundwater (RTD) and surface water levels, there is the potential that the Pymmes Brook is hydraulically connected to groundwater beneath the site, albeit this connection is likely to be limited by engineered structures around the brook. It is also considered likely that the interaction between surface water and groundwater beneath the site changes throughout the reach along the site boundary, with groundwater levels observed at the site higher in the north of the site (localised flow away from the brook) and groundwater levels observed lower in the south of the site (localised flow towards the brook). It is also considered likely that the RTD is hydraulically connected to the River Lee and River Lee Diversion to the east of the site. The River Lee Navigation Channel and Reservoir system are considered likely to be hydraulically disconnected from groundwater due to their engineering. It is noted that the Reservoir system is partially fed from water from the River Lee and River Lee Diversion (i.e. local surface water).

Groundwater within the Made Ground is considered to represent a source and not a controlled waters receptor. Based on the understanding that Pymmes Brook is culverted and observed groundwater levels within the Made Ground, it is not thought that the Made Ground is directly discharging into the Brook. Due to the heterogeneity of the Made Ground and observed water levels within the unit, any flow within the unit is likely to be irregular.

Where present, the Alluvium appears to be acting as an aquitard, hydraulically separating water within the Made Ground and groundwater within the RTD. Where the Alluvium is absent (in the south of the site), observed water levels within the RTD are considerably higher than that observed across the remainder of the site. This is likely indicating a recharge zone for groundwater within the RTD.

The assessment has considered both surface water receptors and groundwater as controlled water receptors.

Based on the CSM, SSAC values have been developed using the Environment Agency's Remedial Targets Methodology Worksheet V3.2. The calculated SSACs for both the baseline and future scenarios, when screened against available site data, indicated a large percentage of exceedances within soil, soil-leachate and groundwater for ammonium and organic contaminants. These exceedances have been analysed and discussed in this report, where persistent exceedances exist within the available data sets (2013 and 2023) these are considered ongoing risks to controlled waters receptors.

Further assessment has identified the following potentially unacceptable risks:

- Ammonium concentrations observed in groundwater represent a potential unacceptable risk to controlled waters receptors, the source of the dissolved phase ammonium is considered to be either the degradation of onsite organic contamination or from the migration of offsite contamination from the wider area (gas works);
- NAPL present within the site boundary is considered to be an ongoing source of organic contamination to groundwater which poses a potentially unacceptable risk to controlled waters;
- Soil in the north of the site described as 'sweet smelling' in the logs may present an unacceptable risk to controlled waters, no groundwater (RTD) data is available to fully assess this potential risk; and
- Impacted soil within the vicinity of BH12-04, BH23-04 and BH23-05.

Considering the risks, the following next steps are recommended:

- Completion of a Remediation Strategy and options appraisal that will detail mitigation measures to address identified potentially unacceptable risks to controlled waters receptors;
- Possible further investigation at the site to refine and delineate identified source areas, and to address uncertainties in the ground conditions; and
- Continued engagement with the Environment Agency.

9. References

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Figures

Figure 1 – Site Location Plan

Figure 2 – Site Layout

Figure 3 – Historical Features Plan

Figure 4 – Exploratory Hole Plan

Figure 5 – Groundwater Surface Water Levels

Figure 6 – Cross Section North South

Figure 7 – Cross Section East West

Figure 8 – Geological Cross Section Plan

Figure 9 – Potential Sources