

Shell UK Oil Products Limited

Shell Whitemare Pool Fuel Retail Station

Comprehensive Groundwater Monitoring Event Report

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Where field investigations have been carried out, these have been restricted to a level of detail required to achieve the stated objectives of the work.

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1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by Shell UK Oil Products Limited (Shell) to carry out a groundwater monitoring event (GME) at Shell Whitemare Pool fuel retail station, located at Whitemare Pool, Gateshead, Tyne & Wear, NE10 8YB. The location of the site is shown on Figure 1.

This report details a GME conducted at the site by RSK on 24 and 25 February 2021. Given previous uncertainties regarding groundwater elevations and groundwater flow direction beneath the site, two further monitoring visits were conducted on the 27 May and 24 June 2021 to gauge groundwater levels only. This report provides an updated assessment of the environmental status of the site, and is preceded by following previous assessment reports:

- RSK Soil Verification Report (ref. 310714-R1(01)), April 2009
- AECOM Phase 1 Environment Site Assessment Report (ref. GB-10019383-20190820-SA-1), August 2019
- AECOM Comprehensive Environmental Site Assessment Report (ref: GB-10019383-20200929-SA-CESA), September 2020.

For ease of reference, the above AECOM reports will be referred to as the “AECOM Phase 1” and the “AECOM CESA” respectively in subsequent sections.

This report is subject to RSKs service constraints presented in Appendix A.

1.1 Objectives

The objective of the work is to provide information to assess the site’s current environmental status in support of Shell’s asset management programme.

1.2 Scope of work

During the February 2021 GME five pre-existing monitoring wells were gauged to determine depth to groundwater and the presence (and thickness) of any light or dense non-aqueous phase liquids (LNAPL or DNAPL), if present, using an electronic interface probe.

Groundwater samples were taken using a “low flow” purging and sampling technique, following stabilisation of water quality parameters that were monitored in-situ during purging. The monitoring wells selected for sample collection were MW101, MW102, MW103, MW105 and MW109. MW106 could not be sampled owing to a blockage in the monitoring well pipe at shallow depth.

Monitoring well locations are presented on Figure 2, and the low flow data sheets which present the in-situ water quality parameters recorded during monitoring are presented in Appendix C.

The samples were dispatched to a UKAS accredited laboratory (Envirolab Ltd) and scheduled for a site-specific suite of testing, comprising the following COPC (constituents of potential concern):

- speciated total petroleum hydrocarbons (TPHCWG)
- benzene, toluene, ethyl benzene and xylene (BTEX) compounds
- a suite of fuel oxygenates comprising methyl tert-butyl ether (MTBE), ethyl tert-butyl ether (ETBE), di-isopropyl ether (DIPE), tert-butyl alcohol (TBA), tert-amyl methyl ether (TAME) and ethanol
- speciated polycyclic aromatic hydrocarbons (PAH), including naphthalene
- lead scavengers comprising: 1,2-dibromoethane (ethylene dibromide - EDB) and 1,2-dichloroethane (ethylene dichloride - EDC)
- 2-methylnapthalene
- n-hexane
- speciated phenols.

The COPC chosen for assessment replicate those determined and undertaken within the preceding phases of investigation.

In addition, the following quality assurance / quality control (QA/QC) samples were taken:

- a duplicate sample was obtained from monitoring well MW102 – labelled “QAQC Duplicate”
- a (field) equipment blank sample was obtained – labelled “QAQC Blank”.

All quality assurance samples were scheduled for the full suite of COPC mentioned above.

The above works were to be reported within a comprehensive GME report (this report), incorporating a controlled waters detailed quantitative risk assessment (DQRA) if required.

2 SITE SETTING & BACKGROUND

2.1 Site setting and description

The site is currently an active petrol filling station located at a service station area adjacent to the A194 dual carriageway, with a hotel and restaurants located adjacent to the south of the site. A substation is located within the north western area of the site. The site is located at Shell Whitemare Pool, Whitemare Pool, Gateshead, Tyne & Wear, NE10 8YB, Ordnance Survey National Grid reference NZ 31200 61570. The site covers an area of approximately 4,600 square metres (m^2) and is located at an approximate elevation of 50m Above Ordnance Datum (AOD).

The site is bound to the north by Roman Road and dense vegetation. Approximately 115m north east of site is currently part of Red Barns Quarry, which extracts brick shale. To the south and east the site is bound by A194 dual carriageway (Leam Lane). The site is bound to the west by commercial buildings which include a service station and Travelodge.

The site layout is shown in Figure 2.

2.2 Previous reports

The following previous reports have been produced in relation to the site:

- RSK Soil Verification Report (ref. 310714-R1(01)), April 2009
- AECOM Phase 1 Environment Site Assessment Report (ref. GB-10019383-20190820-SA-1), August 2019
- AECOM Comprehensive Environmental Site Assessment Report (ref: GB-10019383-20200929-SA-CESA), September 2020.

For ease of reference, the above AECOM reports will be referred to as the “AECOM Phase 1” and the “AECOM CESA” respectively in subsequent sections.

The AECOM CESA is summarised further in Section 2.2.1 below and salient background information contained within the above reports is summarised within this section, though the individual reports should be consulted for detailed information.

2.2.1 AECOM comprehensive environmental site assessment report, September 2020

AECOM undertook a Phase 2 Environmental Site Assessment in November 2019. This comprised drilling nine boreholes to a maximum depth of 15 m below ground level (bgl). Six of these boreholes were installed with monitoring wells (MW101-MW103, MW105, MW106 and MW109). MW103 was installed to 2.00 m bgl within the superficial Pelaw Clay, with the other remaining monitoring wells installed in the underlying bedrock between 6.6 m and 9.5 m bgl. Three vapour monitoring wells (VP101 – VP103) were also installed.

There were no visual or olfactory observations of COPC during the investigation in the soil samples collect other than some black pockets of staining in MW106 between 4.95 m and 6.60 m bgl. Hydrocarbon odours were reported in groundwater samples collected

from MW102 located south east of the forecourt and MW106 located west of the tank farm. Asbestos screening was carried out in seven made ground samples, but was not identified.

A Generic Quantitative Risk Assessment (GQRA) was completed using the data collected during the intrusive works to assess potential risks to human health and controlled waters (Secondary A Aquifer and Monkton Burn). Concentrations of COPC in soil were considered unlikely to represent an unacceptable risk to human health receptors, however potentially unacceptable risks were identified to groundwater due to concentrations of BTEX in one monitoring well in the east of the site (MW102).

Groundwater levels recorded by AECOM suggested that MW102 may not be hydraulically connected with the rest of the monitoring well network, given this AECOM concluded that a Detailed Quantitative Risk Assessment (DQRA) could not be completed to further assess risks to the Secondary A Aquifer and Monkton Burn.

2.3 Geology

The geological map for the area, as indicated on the British Geological Survey (BGS) "Geology of Britain" online viewer indicates that the site is underlain by site to be underlain by superficial deposits of the Pelaw Clay Member overlying bedrock. The bedrock comprises the Pennine Middle Coal Measures Formation, anticipated to comprise sandstone across the majority of the site and mudstone, siltstone and sandstone in the northern most section of the site. The maps also show the Claxheugh Fault, trending east to west through the northern part of site. The BGS vertical section indicates an upthrow of between 50 m and 75 m.

Previous intrusive investigation works carried out by AECOM at the site confirmed the following geological succession to be present:

- Made Ground: comprising concrete and asphalt overlying reworked sandy gravelly clay from surface to between 0.4 and 1.7 m bgl
- Pelaw Clay Member: comprising sandy gravelly clay from minimum 0.3 m bgl a maximum depth of 3.1 m bgl
- Pennine Middle Coal Measures Formation: generally comprising brown or grey interbedded horizons of sandstone (fractured in places), siltstone, grey mudstone and shale from minimum depth of 2.7 m bgl to maximum depth of 7.3 m bgl. Variations in the bedrock geology were reported during the investigation, with MW101 and MW106 in the south of the site comprising sandstone underlain by mudstone to the maximum depth of the boreholes (10 m bgl). In the central and northern areas of the site (MW103, MW105 and MW109), interbedded horizons of mudstone and siltstone were identified with sandstone beneath in MW105 and MW109, drilled to a maximum depth of 15 m bgl. Bedrock in MW102 was reported to comprise sandstone between 2.8 m and the maximum drilled depth of 10.0 m bgl. The report concluded that the Claxheugh Fault, identified on geological maps as running through the site, was likely to be present and explained the variations observed in the bedrock geology beneath the site.

2.4 Hydrogeology and hydrology

The AECOM CESA report indicates that the site is not located within an Environment Agency defined source protection zone (SPZ). The Environment Agency classifies the Pelaw Clay Member as Unproductive Strata and the Pennine Middle Coal Measures Sandstone and Sandstone, Siltstone and Mudstone as a Secondary A Aquifer. The nearest Principal Aquifer is located approximately 6 km to the south east of the site.

The AECOM CESA (2020) reports there are no licensed or private records of groundwater abstractions are identified within 2km of the site.

Depth of resting groundwater has been reported during previous investigations between 0.40 m and 0.47 m within superficial clay deposits, and 4.18 m and 9.25 m bgl within wells installed across bedrock.

During the preceding GMEs detailed in the AECOM CESA report, groundwater was encountered in all six installed monitoring wells. Perched water was present between 0.40 m and 0.47 m bgl in MW103 installed in the Pelaw Clay, and between 4.18 m bgl (MW101) in the south west and 9.25 m bgl (MW109) in the north east of the site. Groundwater in MW101 and MW106 was reported to be higher in the south of the site than in MW102 in the east and MW105 and MW109 in the north. AECOM concluded that groundwater flow direction could not be determined owing to large variations in groundwater elevations during the return monitoring visits. The report indicated that groundwater within the bedrock may be influenced by the Claxheugh Fault, which is understood to run east to west through the northern part of the site.

Hydraulic conductivity tests were carried out at three locations (MW101, MW102 and MW109) screening the Pennine Middle Coal Measures Formation. Average hydraulic conductivity values were calculated at 2.98 m/d (MW101), 0.17 m/d (MW102) and 0.06 m/d (MW109).

The nearest surface water feature is an unnamed drain approximately 30 m north west of the site (AECOM, 2020) at its closest point. However, previous investigations have been unable to confirm the presence of water in the drain, due to the presence of dense vegetation. The nearest classified water course is Monkton Burn located approximately 280 m south east of the site at its closest point and runs to the east and north east of the site. The AECOM report considered the groundwater in the Pennine Middle Coal Measures Formation to be in hydraulic connectivity with Monkton Burn.

3 EXISTING CONCEPTUAL SITE MODEL

In order to produce a conceptual site model (CSM), potential sources of COPC together with potential receptors that can be impacted and pathways connecting the source and receptor must be identified. A potential concern exists when a potentially complete pollutant linkage is present, i.e. a possible source and a potential receptor are identified and connected by a plausible pathway.

A conceptual site model (CSM) was first developed in the AECOM Phase 1 Report (2020). From review of the AECOM Phase 1 report, the following potential sources/pathways and receptors were identified on site.

3.1 Potential sources

3.1.1 Potential on-site primary sources

The following potential primary sources of hydrocarbon COPC were identified on site:

- petrol/ diesel as LNAPL arising from potential releases from fuel storage tanks and fuel lines
- petrol/ diesel as LNAPL arising from potential releases from fuel dispensing infrastructure (underground pump lines, pump islands)
- potential petroleum hydrocarbon COPC arising from potential releases from surface drainage interceptors and drainage.

3.1.2 Potential on-site secondary sources

The following potential secondary sources of hydrocarbon COPC were identified on site:

- soil impacted with retail petroleum COPC
- dissolved phase retail petroleum COPC within groundwater
- soil vapour originating from retail petroleum COPC.

3.2 Potential pathways

Human health:

- permeation of plastic pipework
- particulate – ingestion, inhalation, dermal contact, with soil particulates
- volatilisation and subsequent vertical and lateral migration of vapours via permeable strata / along backfill to service trenches.

Controlled waters:

- leaching from unsaturated zone soils
- remobilisation; and lateral and/or vertical migration.

3.3 Potential receptors

The following potential receptors were identified in the AECOM Phase 1:

- on-site shop staff, visiting staff and general public
- visiting contractors excavating ground
- off-site workers and visitors in commercial properties to the south west of the site
- surface water (Unnamed drain approximately 68m west of site but potentially as close as 30m north west of site, Monkton Burn 280m south east at its closest point and ponds 155m south west and 300m north east of site)
- perched groundwater within the Pelaw Clay Member (Unproductive Strata) and Pennine Middle Coal Measures Formation (Secondary A Aquifer).

3.4 Potentially complete pollutant linkages

The following potentially complete pollutant linkages were identified in the AECOM Phase 1 (2020):

- potentially impacted soils / groundwater, followed by permeation through plastic pipes into the site potable water supply
- potentially impacted soils / groundwater, followed by soil particulate dermal contact, inhalation or ingestion by visiting contractors excavating the ground
- potentially impacted soils from the site, followed by leaching of hydrocarbon substances into perched groundwater in the Pelaw Clay Member (Unproductive Strata) or groundwater in the Pennine Middle Coal Measures Formation (Secondary A Aquifer)
- potentially impacted soils/groundwater from the site, followed by migration of impacted groundwater to the identified surface water receptors (drain 68 m west but potentially as close as 30 m north west, Monkton Burn 280 m south east and ponds 155 m south west and 300 m north east of site).

Following the intrusive investigation completed by AECOM in 2020, a number of potentially complete pollutant linkages remained. These were:

- potentially impacted soils / groundwater, followed by soil particulate dermal contact, inhalation or ingestion by visiting contractors excavating the ground*
- COPC in soils - leaching into groundwater in the Pennine Middle Coal Measures Formation (Secondary A Aquifer)
- COPC in groundwater – lateral and vertical migration in the dissolved phase – towards the identified down gradient surface water receptors (drain 68 m west, but potentially as close as 30 m north west, Monkton Burn 280 m south east and ponds 155 m south west and 300 m north east of site).

*The risk of this linkage occurring was noted as possible, however the potential for direct contact with soil particulates by on-site contractors would likely be managed by appropriate use of PPE under CDM Regulations and therefore has not been considered any further.

As already mentioned, groundwater levels recorded by AECOM suggested that MW102 may not be hydraulically connected with the rest of the monitoring well network. Therefore, AECOM concluded that the potentially complete linkages presented above in relation to controlled waters could not be assessed further via DQRA.

3.4.1 AECOM CSM review, data gaps and uncertainties

The following data gaps and uncertainties have been identified from the AECOM CESA:

- the CSM does not consider migration of COPC through preferential pathways such as the Claxheugh Fault or fractured bedrock. The AECOM borehole records indicate the presence of fractured sandstone in MW101 and MW106 in the south of the site
- uncertainties remain with regards the presence and location of the Claxheugh Fault beneath the site. British Geological Survey maps indicate that it may run through the northern half of the site, trending in an east to west direction. The AECOM CSM, however, places the fault as running through the south of the site, beneath the tank farm. A review of the borehole logs indicates a change in geology beneath the site shop, between monitoring wells MW103 and MW105. From MW105 northwards geology comprises interbedded siltstones, sandstones and shales, whereas to the south of the shop the geology is generally characterised by sandstones and mudstones, interbedded in places
- AECOM were unable to derive a groundwater flow direction due to varying groundwater elevations encountered during the return monitoring visits. The first monitoring rounds indicated that there was a general flow to the north east towards the Monkton Burn, however a drop in groundwater elevations was recorded in MW102, MW105 and MW109 between December 2019 and February 2020 leading AECOM to conclude that the monitoring wells may not be in hydraulic connectivity with each other. Because of this, AECOM concluded they were unable to complete a DQRA
- there are gaps in coverage for monitoring wells across the site. MW103 for example was completed to a comparatively shallow depth than the other monitoring wells, which has mean that deeper bedrock between the south of the site and the anticipated location of the fault hasn't been characterised. MW103 was also the only monitoring well installed within the perched groundwater in the superficial Pelaw Clay deposits. Furthermore, MW106 became blocked following the February 2020 monitoring round, meaning no further samples could be obtained from this location.

4 RESULTS

4.1 Groundwater gauging results

The results of the groundwater gauging are presented in Table 1, Table 2 and Table 3. Given the previous uncertainties regarding the groundwater flow highlighted in the AECOM CESA report, three groundwater gauging rounds were completed between February and June 2021.

Groundwater elevations were obtained by a GPS level survey of the highest elevations of the monitoring well casing during works conducted in support of the preceding AECOM CESA Report.

During the February GME gauging, groundwater was encountered at depths of between 0.28 m (MW103) and 5.82 m (MW105) below top of pipework level (btop). Water levels in MW103 are considered to be representative of groundwater within the superficial clay deposits. Water levels in monitoring wells MW101, MW102, MW105 and MW109 ranged between 4.0 m and 5.82 m btop are considered to be representative of groundwater in the Pennine Middle Coal Measures Secondary A aquifer. Groundwater levels recorded in the Pennines Middle Coal Measures in May and June 2021 ranged between 1.70 m and 9.95 m btop.

Monitoring well MW106 was blocked by an obstruction at shallow depth and therefore a depth to water measurement could not be recorded during the gauging works.

LNAPL or DNAPL were not detected during the monitoring events.

Table 1: Groundwater gauging results 24/02/2021

Location	Top of Pipe Elevation (mAOD)	Depth to Water (mbTOP)	Depth to Base (mbTOP)	Groundwater Elevation (mAOD)
MW101	49.87	4.00	6.73	45.86
MW102	49.71	5.27	9.36	44.44
MW103	49.52	0.28	1.1	49.25
MW105	49.23	5.82	7.86	43.39
MW106	Blocked			
MW109	49.35	5.74	9.37	43.62
Notes: mbTOP: metres below top of pipe; mAOD: metres above Ordnance Datum				

Table 2: Groundwater gauging results 27/05/2021

Location	Top of Pipe Elevation (mAOD)	Depth to Water (mbTOP)	Depth to Base (mbTOP)	Groundwater Elevation (mAOD)
MW101	49.87	Engineer unable to locate		
MW102	49.71	8.27	9.55	41.44

Location	Top of Pipe Elevation (mAOD)	Depth to Water (mbTOP)	Depth to Base (mbTOP)	Groundwater Elevation (mAOD)
MW103	49.52	0.20	1.72	49.34
MW105	49.23	7.73	8.05	41.50
MW106	Blocked			
MW109	49.35	Dry	9.95	Dry
Notes: mbTOP: metres below top of pipe; mAOD: metres above Ordnance Datum				

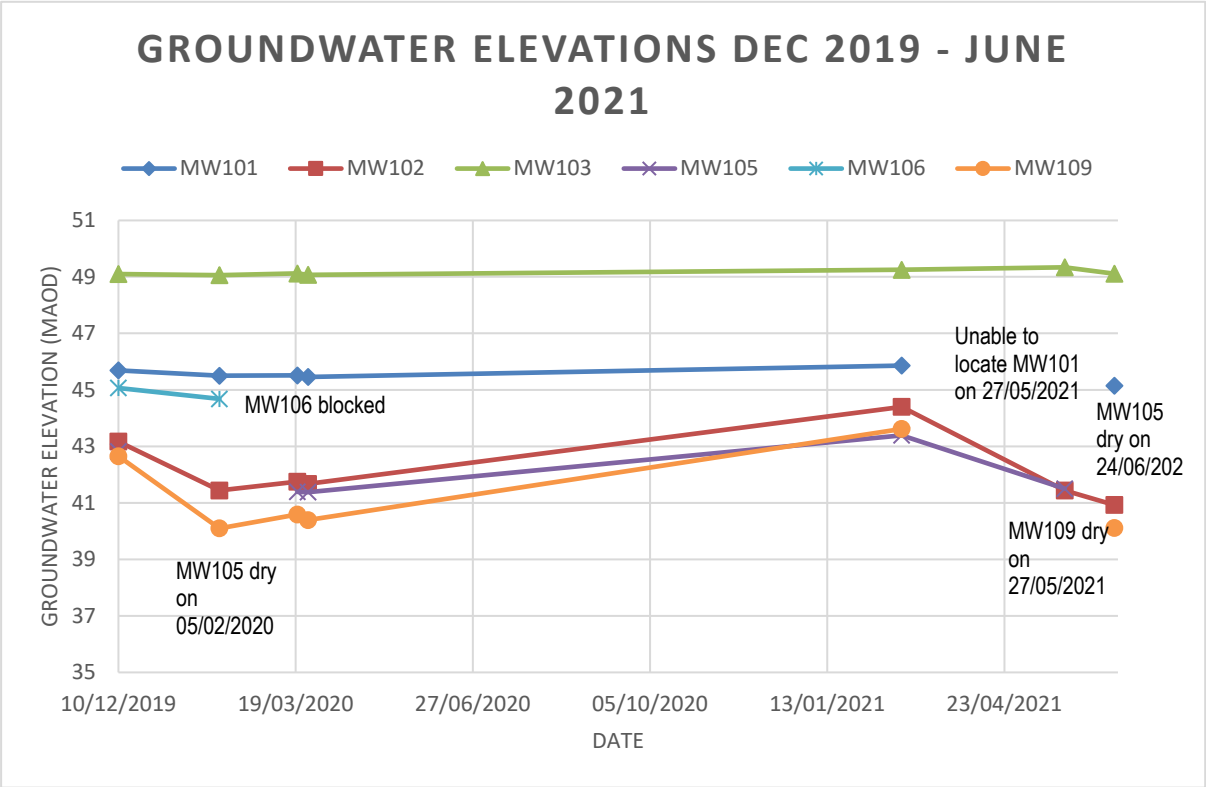
Table 3: Groundwater gauging results 25/06/2021

Location	Top of Pipe Elevation (mAOD)	Depth to Water (mbTOP)	Depth to Base (mbTOP)	Groundwater Elevation (mAOD)
MW101	49.87	4.70	6.73	45.15
MW102	49.71	8.78	9.37	40.93
MW103	49.52	0.42	1.70	49.11
MW105	49.23	Dry	7.86	Dry
MW106	Blocked			
MW109	49.35	9.26	9.37	40.11
Notes: mbTOP: metres below top of pipe; mAOD: metres above Ordnance Datum				

From the dataset as shown on Chart 1 overleaf, there appears to be a correlation between groundwater elevations and time of year, with lower elevations recorded during the summer months and higher in the winter months in monitoring wells MW102, MW105 and MW109 screened within the Pennine Coal Measures bedrock. Groundwater elevations in monitoring wells MW101 and MW103 appear to be more stable over time with minimal seasonal variations noted. Furthermore, the presence of the Claxheugh Fault beneath the site may also affect groundwater elevations.

AECOM concluded they were unable to derive a groundwater flow direction from the data obtained from their monitoring rounds. However, RSK have produced groundwater contour plans, presented as Figures 2a to 2d, using the AECOM groundwater elevations recorded in the monitoring wells screened within the Pennine Middle Coal Measures. The plots indicate a general flow to the north east or east north east of the site, towards Monkton Burn. The RSK February 2021 monitoring round data is presented in Figure 2e, and indicates a general groundwater flow in the bedrock deposits to the north east. The additional groundwater gauging carried out by RSK in June 2021 generally concurs with a flow direction inferred to the east north east, as shown on Figure 2f, however, it is noted that this plot was produced using data from MW101, MW102 and MW109 only as MW105 was dry during the visit. It was not possible to produce a groundwater contour plot from the May 2021 round as MW101 could not be located, MW106 was blocked and MW109 was dry, leaving only two monitoring wells installed within the bedrock containing groundwater (MW102 and MW105).

Chart 1: Groundwater elevations December 2019 to June 2021



A geometric mean of 0.019 for hydraulic gradient has been calculated for the site using the groundwater elevations recorded in MW102 and MW109 by AECOM and RSK. The distance between these two locations is circa 50m.

4.2 Chemical testing results

Laboratory results above the Laboratory Method Detection Limit (LMDL) from groundwater samples collected in February 2021 are summarised in Table 4.

The full laboratory analytical report is presented in Appendix D. Figure 3 presents a summary of selected analytical results for each sampled monitoring well on a plan of the site.

Table 4: Selected COPC concentrations in groundwater samples (µg/l) – February 2021

Location	MW101	MW102	MW103	MW105	MW109	QAQC1 (Duplicate sample from MW102)
Hexane (n-Hexane)	<LMDL	8	<LMDL	<LMDL	<LMDL	7
2-Methylnaphthalene	<LMDL	11	<LMDL	<LMDL	<LMDL	6
Phenol	<LMDL	0.03	<LMDL	<LMDL	<LMDL	0.02
Cresols	<LMDL	0.1	<LMDL	<LMDL	<LMDL	0.11
Xylenols	<LMDL	0.02	<LMDL	<LMDL	<LMDL	0.04
Ali >C5-C6	<LMDL	65	9	4	1	57
Ali >C6-C8	3	185	<LMDL	<LMDL	<LMDL	160
Ali >C8-C10	<LMDL	138	<LMDL	<LMDL	<LMDL	93
Ali >C21-C35	<LMDL	52	<LMDL	<LMDL	<LMDL	61
Total Aliphatics	<LMDL	440	9	<LMDL	<LMDL	371
Aro >C5-C7	<LMDL	193	<LMDL	<LMDL	<LMDL	159
Aro >C7-C8	<LMDL	733	<LMDL	<LMDL	<LMDL	623
Aro >C8-C10	<LMDL	14000	<LMDL	<LMDL	<LMDL	13100
Aro >C10-C12	<LMDL	2090	<LMDL	<LMDL	<LMDL	2000
Aro >C12-C16	<LMDL	168	<LMDL	<LMDL	<LMDL	167
Total Aromatics	<LMDL	17300	<LMDL	<LMDL	<LMDL	16100
TPH (Ali & Aro >C5-C35)	<LMDL	17700	<LMDL	<LMDL	<LMDL	16500
BTEX - Benzene	<LMDL	193	<LMDL	<LMDL	<LMDL	159
BTEX - Toluene	<LMDL	733	<LMDL	<LMDL	<LMDL	623
BTEX - Ethyl Benzene	<LMDL	195	<LMDL	<LMDL	<LMDL	157
BTEX - m & p Xylene	<LMDL	1259	<LMDL	<LMDL	<LMDL	1088
BTEX - o Xylene	<LMDL	657	<LMDL	<LMDL	<LMDL	575
MTBE	<LMDL	13	10	4	1	12

4.2.1 Summary of results

The majority of monitoring wells sampled demonstrate COPC concentrations below or near to the LMDL, with the exception of MW102. A summary of the February 2021 results is listed below:

- concentrations of TPH aliphatics >C5-C6 were detected above the LMDL in MW102, MW103, MW105 and MW109; with a maximum concentration on 65 µg/l in MW102
- concentrations of a number of TPH aliphatic and aromatic bands were recorded above LMDL in MW102. The sum TPH concentration (aliphatics and aromatics >C5-

C35) in MW102 was recorded at 17700 µg/l in the parent sample and 16500 µg/l in the duplicate sample. Sum TPH concentrations in all other monitoring wells locations were below the LMDL of 10 µg/l

- concentrations of BTEX range compounds were recorded above their respective LMDLs in MW102 only, with sum BTEX concentrations reported at 3037 µg/l in the parent sample and 2602 µg/l in the duplicate sample
- no concentrations of the fuel oxygenates ETBE, DIPE, TBA, or ethanol were recorded above their respective LMDLs within any of the six groundwater samples analysed;
- concentrations of MTBE were detected above the LMDL from all samples excluding MW101, with a maximum concentration of 13 µg/l recorded in the parent sample from MW102
- Concentrations of PAHs (total 16) were recorded below the LMDL in all samples.

4.3 Quality assurance / quality control assessment

This section provides a QAQC assessment of observations made in the field and data obtained. QAQC processes provide a line of evidence to interpret whether the laboratory data used in further interpretation is reliable and representative of actual field conditions.

4.3.1 Assessment of data consistency with existing CSM

An assessment has been made of field and laboratory observations against our existing conceptual understanding of the site, as outlined in Section 3. This indicates:

- the distribution of COPC recorded at the site is broadly in line with that recorded during preceding site assessments (further assessment of COPC trends and distribution is included in Section 4.5)
- the laboratory analytical results recorded from all monitoring locations are generally considered consistent with visual and olfactory observations recorded during groundwater sampling
- the results of geochemical groundwater parameter monitoring during purging and sampling generally appear consistent with one another indicating, mildly anaerobic conditions in monitoring wells MW101 and MW109, with moderate to strongly anaerobic conditions in MW102, MW103 and MW105
- from review of groundwater elevations recorded by AECOM and RSK at the site, groundwater flow direction appears to be consistently to the north east or east north east of the site within the Pennine Middle Coal Measures. However, there remains some uncertainty associated with groundwater flow direction, given the anticipated presence of the Claxheugh Fault in the southern portion of the site (based on ground conditions recorded in the AECOM borehole records), the number of monitoring wells screened in the Coal Measures and their distribution across the site
- samples have been analysed at the laboratory for the suite of COPC identified within the existing CSM and that originally proposed within the scope of works

- the resting groundwater table was sat above the screened section of the following monitoring wells during the RSK monitoring works, and as such in the event that LNAPL were to be present in these locations it would not be observed:
    - 24 February 2021 visit – MW102, MW103 and MW109
    - 27 May 2021 visit – MW103 (location MW101 unable to be located, MW106 and MW109 dry)
    - 24 June 2021 visit – MW103 (locations MW105 and MW106 dry).

Measured concentrations of COPC in MW103, MW105, MW106 and MW109 were all below or close to their respective LMDL and LNAPL was not recorded in MW102 in the May and June 2021 groundwater level monitoring visits. Therefore, it is therefore considered unlikely that a measurable source of LNAPL is present in these locations.

4.3.2 Assessment of laboratory QAQC samples

An assessment has been made of the results obtained from laboratory QAQC samples. This indicates:

- a suitable number of QAQC samples are considered to have been obtained during the monitoring round, comprising a (field) equipment blank and a field duplicate sample
- analytical results from the field blank sample QAQC Blank were all found to be below the LMDL with the exception of TPH aliphatic >C6-C8, which was reported at the LMDL of 1 µg/l
- calculation of the relative percentage difference (RPD) was undertaken between selected COPC concentrations recorded within the primary sample from MW102, and that recorded within the duplicate sample (labelled QAQC Duplicate). The following calculated RPD percentages are considered acceptable:
    - a resultant RPD percentage of 7.02% was calculated for TPH (>C5 to C35)
    - a resultant RPD percentage of 19.32% was calculated for benzene
    - a resultant RPD percentage of 16.22% was calculated for toluene
    - a resultant RPD percentage of 14.57% was calculated for m & p xylene
    - a resultant RPD percentage of 13.31% was calculated for o xylene
    - a resultant RPD percentage of 8.00% was calculated for MTBE
- all samples were submitted to a suitable UKAS/MCERTS accredited analytical laboratory. No sample deviations were recorded by the analytical laboratory. A deviating sample is defined as one that may have been compromised in some way during sampling, transportation, storage, or analysis
- PAH results were reported as insufficient sample (IS) due to a laboratory QC failure, whereby there was insufficient sample remaining to perform a re-test of all samples
- the LMDLs achieved through analytical testing are considered suitably low, in order to allow an onward comparison against risk-based criteria.

4.3.3 Summary

Based on the assessment of QAQC parameters, the monitoring data obtained during the current scope of works is considered suitable for further interpretation and risk-based assessment. The data obtained is also considered consistent with RSKs current understanding of the CSM.

4.4 Aquifer conditions

4.4.1 In-situ water quality parameter monitoring

In-situ water quality parameters (pH, temperature, electrical conductivity, redox potential and dissolved oxygen) were collected during the low-flow groundwater purging and sampling visit undertaken on 24 and 25 February 2021, and are summarised within below and presented in full within Appendix C.

Assessment of these stabilised parameters provides an indication of the geochemical characteristics of the aquifer and are summarised in Table 5.

Table 5: In-situ groundwater quality results

Location	Dissolved Oxygen (DO) (mg/l)	Indicative Aquifer Conditions (based on DO)	Redox* (mV)	Indicative Aquifer Conditions (based on Redox)	Electrical Conductivity (µS/cm)
MW101	2.8	Aerobic	194.7	Mildly anaerobic	1306
MW102	0	Strongly anaerobic	65.4	Mildly anaerobic	2257
MW103	0.03	Moderately anaerobic	170	Mildly anaerobic	3237
MW105	0	Strongly anaerobic	180.1	Mildly anaerobic	1455
MW109	0.36	Mildly Anaerobic	176.4	Mildly anaerobic	1729
* In-situ field readings corrected to redox using a conversion factors for an Aquaread water quality meter					

Based upon in-situ field measurements of dissolved oxygen (DO) and REDOX potential measurements, aquifer conditions are considered to be mildly anaerobic in monitoring wells MW101 and MW109, with moderate to strongly anaerobic conditions in MW102, MW103 and MW105.

Strongly anaerobic conditions were identified by dissolved oxygen readings in MW102 and MW105, indicating that methanogenesis may be occurring at these locations.

The assessment overall indicates that the majority of the site may be characterised by moderately anaerobic conditions.

4.5 Trend analysis of COPC concentrations

A summary of the February 2021 results along with the preceding AECOM groundwater monitoring results for selected COPC is presented on Figure 3.

Groundwater laboratory results from previous recorded groundwater monitoring events that have been undertaken at the site were analysed using the GroundWater Spatio-

Temporal Data Analysis Tool (GWSDAT) (v2.1) developed by Shell Global Solutions, in order to visualise trends in groundwater monitoring data.

In order to clearly present trends in groundwater quality, the assessment within the current report includes results from the groundwater monitoring rounds conducted by AECOM in December 2019 and February 2020, and RSK in February 2021.

The GWSDAT output is presented in Appendix E in the form of plume plots showing the interpolated lateral distribution of selected COPC in groundwater and each monitoring event, and also a graphical presentation of concentrations of selected COPC in each monitoring well over time.

It is noted that chemical testing data was not available for MW105 and MW109 during the February 2020 round and MW106 in February 2021 due to a blockage in the monitoring well.

The following trends have been identified from the data:

- concentrations of sum TPH aliphatics >C5-C6 were recorded above the LMDL in December 2019 in monitoring wells MW102 and MW106 only at concentrations of 4870 µg/l and 2290 µg/l respectively. In February 2020, concentrations of sum TPH had marginally (in the same order of magnitude) increased within MW102 to 6160 µg/l and marginally decrease in MW106 to 1190 µg/l. By February 2021, sum TPH had increased by an order of magnitude in MW102 to 17,700 µg/l
- concentrations of benzene were recorded above the LMDL in December 2019 in monitoring wells MW102 and MW106 only at concentrations of 750 µg/l and 8.25 µg/l respectively. In February 2020, concentrations of benzene had marginally (in the same order of magnitude) increased within MW102 to 940 µg/l and decreased in MW106 to below the detection limit of 1 µg/l. By February 2021, benzene had increased to 193 µg/l, however this remains below the concentration recorded in December 2019
- toluene was only recorded above the LMDL in MW102 across the monitoring visits. Toluene was recorded in MW102 in December 2019 at a concentration of 69.2 µg/l. In February 2020, concentrations of toluene increased to 181 µg/l within MW102, and further increased in February 2021 to 733 µg/l
- concentrations of ethylbenzene were recorded above the LMDL in December 2019 in monitoring wells MW102 and MW106 only at concentrations of 753 µg/l and 117 µg/l respectively. In February 2020, concentrations of ethylbenzene had marginally (in the same order of magnitude) decreased within MW102 to 181 µg/l and decreased in MW106 to below the detection limit of 1 µg/l. By February 2021, ethylbenzene had increased to 195 µg/l, however this remains below the concentration recorded in December 2019
- concentrations of total xylenes were recorded above the LMDL in December 2019 in monitoring wells MW102 and MW106 only at concentrations of 536 µg/l and 13.69 µg/l respectively. In February 2020, concentrations of total xylenes had marginally (in the same order of magnitude) increased within MW102 to 947 µg/l and decreased in MW106 to 1 µg/l. By February 2021, total xylene had increased by an order of magnitude to 1916 µg/l

- MTBE concentrations have been recorded above the LMDL in all locations with exception to MW101 across the monitoring period, with the maximum concentrations recorded in MW102. In December 2019 MTBE was recorded at 25.8 µg/l, by February 2020 this marginally (in the same order of magnitude increased to 30.8 µg/l, but by February 2021 MTBE concentrations in MW102 decreased to 13 µg/l.

Overall a concentrations of a number of COPC appear to have increased at MW102 between 2019 and 2021, however concentrations of COPC in the remaining monitoring wells appear to have generally decreased or remained stable.

5 GENERIC QUANTITATIVE RISK ASSESSMENT

The AECOM CESA identified the following potentially complete pollutant linkages for assessment following refinement of the initial CSM:

- COPC in soils - leaching into groundwater in the Pennine Middle Coal Measures Formation (Secondary A Aquifer)
- COPC in groundwater – lateral and vertical migration – towards the identified down gradient surface water receptors (Monkton Burn).

As described in LCRM (Environment Agency, 2020), there are two stages of quantitative risk assessment (QRA), Tier 2 generic (GQRA) and Tier 3 detailed (DQRA). The GQRA comprises the comparison of soil, groundwater, soil gas and ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. This comparison can be undertaken directly against the laboratory results or following statistical analysis depending upon the sampling procedure that was adopted. This assessment relates to LCRM Stage 1, Tier 2 GQRA.

A revised schematic CSM is shown on Figure 4.

Table 6 Linkages for GQRA

Potentially relevant contaminant linkage	Assessment method
Migration of COPC in the dissolved phase towards down gradient surface waters (nearest down gradient surface water receptor considered to be Monkton Burn)	Comparison of groundwater data to relevant GAC based on freshwater Environmental Quality Standard (EQS) in Appendix F.

Groundwater within the Secondary A Aquifer has not been considered as a potential drinking water resource receptor, as the aquifer beneath and immediately surrounding the site does not comprise a Principal Aquifer or an aquifer of strategic importance. Furthermore, information provided in the AECOM CESA report indicates that there are no potable water abstractions within 2 km of the site.

5.1 Methodology and assessment of water results

5.1.1 Dissolved phase migration of COPC to surface waters

Appendix F compares the groundwater analytical results and GAC for Controlled Waters receptors (presented in Appendix F).

The nearest down gradient surface water receptor to the site is considered to be Monkton Burn. This is located circa 280 m from the site at its closest point, therefore the Controlled Waters GAC selected for comparison with the groundwater analytical results are the EQS (or best equivalent) for retail petroleum COPC as presented in Appendix F.

Table 7 provides a summary of the GAC comparison.

Table 7 Summary of groundwater GQRA results with respect to surface waters

Determinand	EQS (µg/l)	Number of exceedances	Max. concentration µg/l (sample ref.)
Benzene	10	2 (MW102 and its duplicate only)	193 (MW102)
Toluene	74		733 (MW102)
m & p xylene	30		1259 (MW102)
o xylene	30		657 (MW02)
Xylenes (sum of)	30		1916 (MW102)

All other COPC were recorded to be present below the applicable GAC.

It is noted that phenols were detected above the LMDL in MW102. Phenols are not considered to be retail petroleum COPC risk driving compounds and no clear on or off - site non-retail petroleum source of phenol has been identified. Given this, and that the nearest down gradient surface water is located beyond 400 m from the site, phenols are not considered risk driving compounds for the site and therefore are not considered further in this assessment.

5.2 GQRA conclusions

Following the GQRA, the following pollutant linkages are considered to remain potentially complete:

- COPC in soils - leaching into groundwater in the Pennine Middle Coal Measures Formation (Secondary A Aquifer)
- COPC in groundwater – lateral and vertical migration – towards the identified down gradient surface water receptors (Monkton Burn).

5.3 Review of data gaps

The following data gaps have been identified:

- a groundwater sample could not be obtained from MW106 during the February 2021 monitoring visit, due to an obstruction at shallow depth in the monitoring well pipe. Observations of COPC were recorded in samples from this monitoring well during the preceding AECOM monitoring rounds. As such, there is a data gap in regard to groundwater quality in this area of the site
- the Claxheugh Fault is understood to run through the site; however the exact location is not clear. BGS maps (1:50,000 scale) show it running in an east to west direction through the north of the site. However, the AECOM borehole records for the site note a change in geology roughly under the kiosk. Siltstones and shale are recorded to the north of the kiosk in MW105 and MW109, which are not recorded to the south in

MW101, MW102, MW103 and MW106. Further investigation would be required to definitively locate the fault

- from review of groundwater elevations recorded by AECOM and RSK at the site, groundwater flow direction appears to be consistently to the north east or east north east of the site within the Pennine Middle Coal Measures. However, there remains some uncertainty associated with groundwater flow direction, given the anticipated presence of the Claxheugh Fault in the southern portion of the site (based on ground conditions recorded in the AECOM borehole records), the number of monitoring wells screened in the Coal Measures and their distribution across the site
- strongly anaerobic dissolved oxygen conditions were recorded in-situ at MW102 and MW105 indicating that methanogenesis may be occurring at these locations, however MNA data to support this conclusion has not been collected to date
- there was no PAH data reported for the February 2021 round, owing to a laboratory QC failure where there was then insufficient sample to re-test
- there is a data gap in groundwater quality to the north east/ east north east of MW102 within which COPC have been identified, as monitoring well location MW103 was installed in the superficial deposits.

6 CONTROLLED WATERS DETAILED QUANTITATIVE RISK ASSESSMENT

6.1 Methodology

The DQRA for controlled waters has been undertaken using the ConSim software package, which was developed by Golder Associates on behalf of the Environment Agency. Further details regarding the ConSim model are presented in ConSim Release 2, Contamination Impacts on Groundwater: Simulation by Monte Carlo Method (Environment Agency, 2003, R&D Publication 132).

ConSim is a forward modelling package and enables predictions of future COPC concentration from known source areas to receptors of interest to be assessed. ConSim is a probabilistic model and allows input parameters to be entered as probability distribution functions (data ranges can be input rather than relying on a single value), which reduces uncertainty in the model. Each time a calculation is carried out, one value from the defined input distribution is chosen by computer code and a concentration at the receptor is calculated. Each iteration is stored such that after repeating the same calculation many times, an output is given in terms of percentiles. These percentiles specify the probability with which a certain value will not be exceeded. The modelling results are assessed at the 95th and 50th percentiles, where the 95th percentile is equivalent to a 5% chance of occurrence and the 50th percentile is equivalent to the most likely scenario. The 95th percentile is considered as acceptable for assessing the potential worst-case result.

A Level 3a simulation has been selected to predict concentrations of dissolved phase COPC at receptor(s) of interest with processes of advection, dispersion, attenuation and degradation considered along the aquif er pathway. The model also enables an assessment of the timescales for COPC to migrate from the source area to the selected receptor(s).

6.2 Model simulation

Table 8 summarises the model simulation considered within the assessment. An electronic copy of the model is included in Appendix G.

Table 8: Model simulation

Model	Description	Source	Receptor
Model 1	Plume migration of key COPC to Monkton Burn	Maximum concentrations recorded in groundwater at MW102 located in the south east of site	Monkton Burn at its closest point down gradient (east north east / north east) circa 470 m

6.3 Selection of COPC

The purpose of the model is to determine whether COPC are impacting the identified controlled waters receptors located potentially down gradient of the site, most notably the Monkton Burn located to the east north east of the site. The following have been selected as retail petroleum COPC indicator compounds for inclusion in the DQRA model, given that they have all be recorded in groundwater beneath the site in excess of their respective EQS:

- benzene
- toluene
- xylene (total).

6.4 Input parameters

Appendix G contains the ConSim model input parameters which are detailed in the sections below.

6.4.1 Source zone

Table 9 below illustrates the groundwater source dimensions considered within the assessment.

Table 9: Source zone input parameters

Input parameter	Units	Distribution	Value(s)	Justification
Width of plume in aquifer at source, perpendicular to groundwater flow	m	Single	40	Maximum concentrations of COPC have generally been observed in MW102 and previously COPC were also identified in MW106 prior to it becoming blocked. Groundwater flow direction has been assumed to the east north east, as this was generally indicated by the historical monitoring data and most recent groundwater gauging rounds. Therefore, for the purposes of this assessment the width of the source has been assumed as the width of the site between MW102 on the eastern boundary and MW106 on the western boundary. This spans the width of the main fuel infrastructure at the site, to encompass the storage tanks, fuel lines and pump islands (perpendicular to groundwater flow).
Length of plume in aquifer at source, parallel to groundwater flow	m	Single	30	Groundwater flow direction has been assumed to the east north east, as this was generally indicated by the historical monitoring data and most recent groundwater gauging rounds. The length of the source has therefore been assumed to be the length of the main fuel infrastructure at the site, to encompass the storage tanks, fuel lines and pump islands.

Input parameter	Units	Distribution	Value(s)	Justification
Centre definition of plume	-	Random sampling	-	Reflective of source concentrations
Infiltration	mm/yr	Triangular	226, 238, 250	Rainfall infiltration rate estimated as a function of total rainfall, effective rainfall and the degree and quality of hardstanding coverage at the site. Rainfall from three nearest UK gauging stations (Wear, Chester-Le-Street; Team, Team Valley; Ouse Burn, Crag Hall) as reported in the Hydrometric Register (Centre for Ecology and Hydrology/BGS, 2008). Effective rainfall for the area of the site was reported from figures 2a and 2b of the Environment Agency Water Resources in England and Wales 2008 report.: Summer 101-125 mm/yr and winter 126-150 mm/yr. The approximate coverage of hardstanding at the site is 51%, with the hardstanding noted to be in poor condition during the site works in February 2021. Based on the above information, infiltration rates have been calculated using the high summer and high winter effective rainfall (250 mm/yr), low summer and low winter effective rainfall (226 mm/yr), and high winter and low summer effective rainfall (238 mm/yr).

6.4.2 Chemical properties

Table 10 illustrates the chemical properties considered within the assessment. The in-situ monitoring results indicate moderately anaerobic conditions are present at the site.

Table 10: Chemical properties

Input parameter	Units	Distribution	Value(s)	Justification
Benzene				
Source concentration	mg/l	Single	0.193	Maximum concentration measured at MW102 during most recent GME in February 2021.
Koc	ml/g	Triangular	60.8, 67.6, 74.4	The recommended Koc value within EA science Report SC050021/SR7 has been varied by +/- 10% to take into account potential variability within this parameter.
Half life	years	Triangular	0.31, 1.14, 1.97	Range of values for anaerobic conditions from Howard et al 1991, Handbook of Environmental Degradation Rates and ConSim. The most likely value reflects the midpoint within the range of values presented.
Toluene				
Source concentration	mg/l	Single	0.733	Maximum concentration measured at MW102 during most recent GME in February 2021.

Input parameter	Units	Distribution	Value(s)	Justification
Koc	ml/g	Triangular	184, 204, 224	The recommended Koc value within EA science Report SC050021/SR7 has been varied by +/- 10% to take into account potential variability within this parameter
Half life	years	Triangular	0.15, 0.36, 0.58	Range of values for anaerobic conditions from Howard et al 1991, Handbook of Environmental Degradation Rates and ConSim. The most likely value reflects the midpoint within the range of values presented.
Xylene (total)				
Source concentration	mg/l	Single	1.916	Maximum concentration measured at MW102 during most recent GME in February 2021
Koc	ml/g	Triangular	383.9, 426.6, 469.3	The recommended Koc value for o-xylene within EA science Report SC050021/SR7 has been varied by +/- 10% to take into account potential variability within this parameter.
Half life	years	Triangular	0.49, 0.74, 0.99	Range of values for anaerobic conditions from Howard et al 1991, Handbook of Environmental Degradation Rates and ConSim. The most likely value reflects the midpoint within the range of values presented.

6.4.3 Aquifer properties

Table 11 presents the input parameters used to model the aquifer.

Table 11: Aquifer properties

Input parameter	Units	Distribution	Value(s)	Justification
Thickness	m	Uniform	5.65, 10.89	Based on proven depth of sandstone of 15 m bgl and range in groundwater elevations from the three 2021 groundwater gauging rounds at MW101, MW102, MW105 and MW109 (representing the Coal Measures aquifer) of 4.11 to 9.35 m bgl.
Dry bulk density	g/cm^3	Uniform	1.60, 2.68	Groundwater flow is predominantly in the sedimentary rock beneath the site, and this comprises beds of sandstone, siltstone and mudstone. Therefore, a range of values for sandstone and mudstone presented within the ConSim Help Files has been applied.
Mixing zone thickness	m	-	-	Calculated within the model

Input parameter	Units	Distribution	Value(s)	Justification
Hydraulic conductivity	m/s	Log triangular	6.60E-7, 3.59E-06, 4.28E-05	The range of site specific values derived from the historic permeability testing results along have been adopted within the assessment (6.60E-7 m/s to 4.28E-5 m/s). The most likely value adopted is the geometric mean of the site specific data (3.59E-6 m/s). It is noted that the lower end of the site specific data only falls within the range of literature values provided in CONSIM for a sandstone (3.0E-10 to 6.0E-6 m/s). This is not unexpected owing to the fractured nature of the bedrock as indicated by the borehole logs.
Effective porosity	-	Uniform	0.12, 0.27	Geology beneath the site is characterised by interbedded sandstones, siltstones and mudstones, therefore a range of values for specific yield characteristic of siltstone to a medium sandstone from McWorter and Sundana (1997).
Hydraulic gradient	-	Triangular	0.010, 0.019, 0.027	A geometric mean of 0.019 and range in values of 0.010 to 0.027 for hydraulic gradient has been calculated for the site using the groundwater elevations recorded in MW102 and MW109 by AECOM and RSK. The distance between these two locations is circa 50 m.
Groundwater flow direction	Degrees	Single	0	For the purposes of the assessment, it is considered that groundwater flow is in a east north east direction. The flow direction has been taken into account by the source dimensions parallel and perpendicular to groundwater flow.
Longitudinal dispersivity	m	Single	5	1/10th of pathway length (50 m to theoretical compliance point).
Transverse dispersivity	m	Single	0.5	1/100th of pathway length.
Fraction organic carbon	%	Uniform	0.0001 – 0.009	No site data, based on ConSim maximum and minimum ranges for mudstone and sandstone aquifer
1001 Correlations				
Hydraulic conductivity vs effective porosity 1				
Time slices (y)				
1, 2, 3, 4, 5, 10, 15, 20, 25, 50, 100, 250, 500, 750, 1000				
Assessment points (distance from downgradient source boundary)				
Point A	m	Single	50	Generic assessment point located 50 m down gradient of the site
Point B	m	Single	470	Surface water receptor the Monkton Burn located 470 m east north east of the site

6.5 Results

The model results sheets are presented in Appendix G as time history plots with the results summarised in Table 12.

Table 12: Modelling results – predicted concentrations at compliance point

Result	Units	Receptor			
		50 m		Monkton Burn	
		95th percentile	50th percentile	95th percentile	50th percentile
Benzene – target concentration 0.01 mg/l					
Predicted time to maximum concentration	Years (5th percentile)	1	15	15	100
Predicted maximum concentration	mg/l	**0.193**	**0.013**	0.0044	8.28E-10
Toluene - target concentration 0.074 mg/l					
Predicted time to maximum concentration	Years (5th percentile)	1	10	15	25
Predicted maximum concentration	mg/l	**0.733**	0.0011	2.46E-05	1.12E-21
Xylene - target concentration 0.03 mg/l					
Predicted time to maximum concentration	Years (5th percentile)	1	15	15	50
Predicted maximum concentration	mg/l	**1.916**	**0.042**	0.0071	1.53E-12
Bold font and shading indicates predicted concentration exceeds of the controlled waters GAC					

The model results indicate that concentrations of benzene, toluene and xylene in groundwater at a distance of 50 m from the site are likely to exceed the controlled waters GAC. However, the model shows that predicted concentrations at the nearest down gradient surface water receptor are below the GAC, by an order of magnitude for benzene and xylenes and three orders of magnitude below the GAC for toluene. Therefore, it is considered that the site is unlikely to be impacting surface water quality in the Monkton Burn.

6.6 Sensitivity analysis

6.6.1 Sensitivity analysis

As parameters are input into ConSim as statistical distributions representing the full range of likely values, the results include an inbuilt sensitivity analysis. The sensitivity is expressed as a number from 1 to -1. The closer the number to 1 or -1, the greater the sensitivity.

The sensitivity analysis was undertaken for the predicted concentrations at the receptor after 100 years (steady state conditions). The results of the sensitivity analysis are presented in Appendix H. For benzene, the most sensitive parameters are indicated to be the hydraulic conductivity, hydraulic gradient and the half-life, with sensitivity values of 0.65, 0.41 and 0.17 respectively. For toluene and xylene, the most sensitive parameters are also indicated to be aquifer hydraulic conductivity hydraulic gradient, but with lower sensitivity values than for benzene.

The saturated hydraulic conductivity values adopted in the model are based on the range of historic site specific data from three monitoring wells installed within the sandstone. It is noted that the lower end of the site specific data only falls within the range of literature values for a sandstone. However, this is not unexpected owing to the fractured nature of the bedrock as indicated by the borehole logs. Given that the full range of site specific hydraulic conductivity data has been used in the model set up, although the model is sensitive to this parameter the assessment results are considered valid.

Similarly, whilst the model is also sensitive to the hydraulic gradient input, values for this parameter are also based on a range of site-specific data. Further to this, the hydraulic gradient values calculated from the recorded on-site groundwater elevations (0.010 to 0.027) are generally consistent hydraulic gradients calculated from the on-site groundwater elevations to the elevation of the Monkton Burn 470 m downgradient of the site (elevation of the burn circa 50 m AOD, calculated gradients 0.0014 to 0.021).

7 CONCLUSIONS

The monitoring described within this report was designed to provide an update on groundwater conditions at the site, following the AECOM CESA in September 2020.

AECOM concluded they were unable to complete a DQRA due to uncertainties with the groundwater flow regime and effect of the Claxheugh Fault present at the site. Following review of the AECOM and RSK groundwater elevation data as general groundwater flow direction to the north east or east north east towards Monkton Burn has been inferred.

Stable or decreasing concentrations of COPC have been recorded at most monitoring wells between 2019 and 2021, however increasing concentrations of toluene and xylene have been recorded in MW102.

The AECOM CESA identified the following potentially complete pollutant linkages for assessment following refinement of the initial CSM:

- COPC in soils - leaching into groundwater in the Pennine Middle Coal Measures Formation (Secondary A Aquifer)
- COPC in groundwater – lateral and vertical migration – towards the identified down gradient surface water receptors (Monkton Burn).

Groundwater within the Secondary A Aquifer has not been considered as a potential drinking water resource receptor, as the aquifer beneath and immediately surrounding the site does not comprise a Principal Aquifer or an aquifer of strategic importance. Furthermore, information provided in the AECOM CESA report indicates that there are no potable water abstractions within 2 km of the site.

Comparison of concentrations from the RSK February 2021 GME with controlled waters GAC, reported exceedances of the GAC for a number of BTEX COPC. A DQRA was therefore completed with respect to surface water receptors to assess potential risks to Monkton Burn located 470 m to the north east of the site at its closest point in the inferred groundwater flow direction.

The DQRA assessment predicted concentrations of benzene, toluene and xylenes above their respective EQS at the theoretical compliance point of 50 m. The DQRA assessment results for the compliance point at 470 m (downgradient distance to Monkton Burn), however, reported predicted concentrations at least 8 orders of magnitude lower than their respective EQS.

Given that the COPC modelled are not predicted to reach Monkton Burn at the 470 m compliance point in excess of their respective EQS, a potential pollutant linkage from dissolved phase migration of COPC from groundwater beneath the site to Monkton Burn is considered unlikely to exist and as such potential risks to the burn are considered low.

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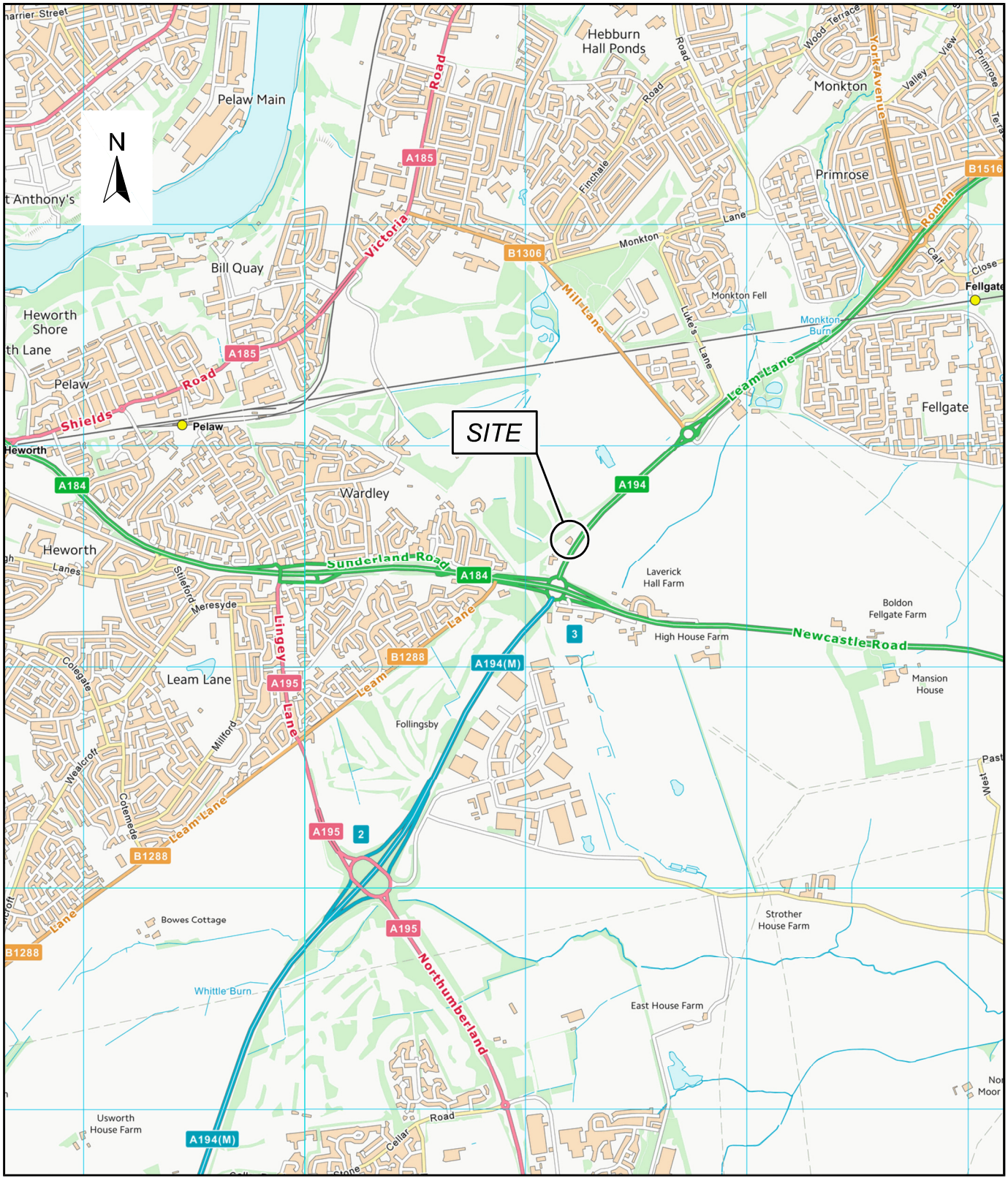
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FIGURES



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Client: Shell UK Oil Products Limited

Project Title: Shell Whitemare Pool

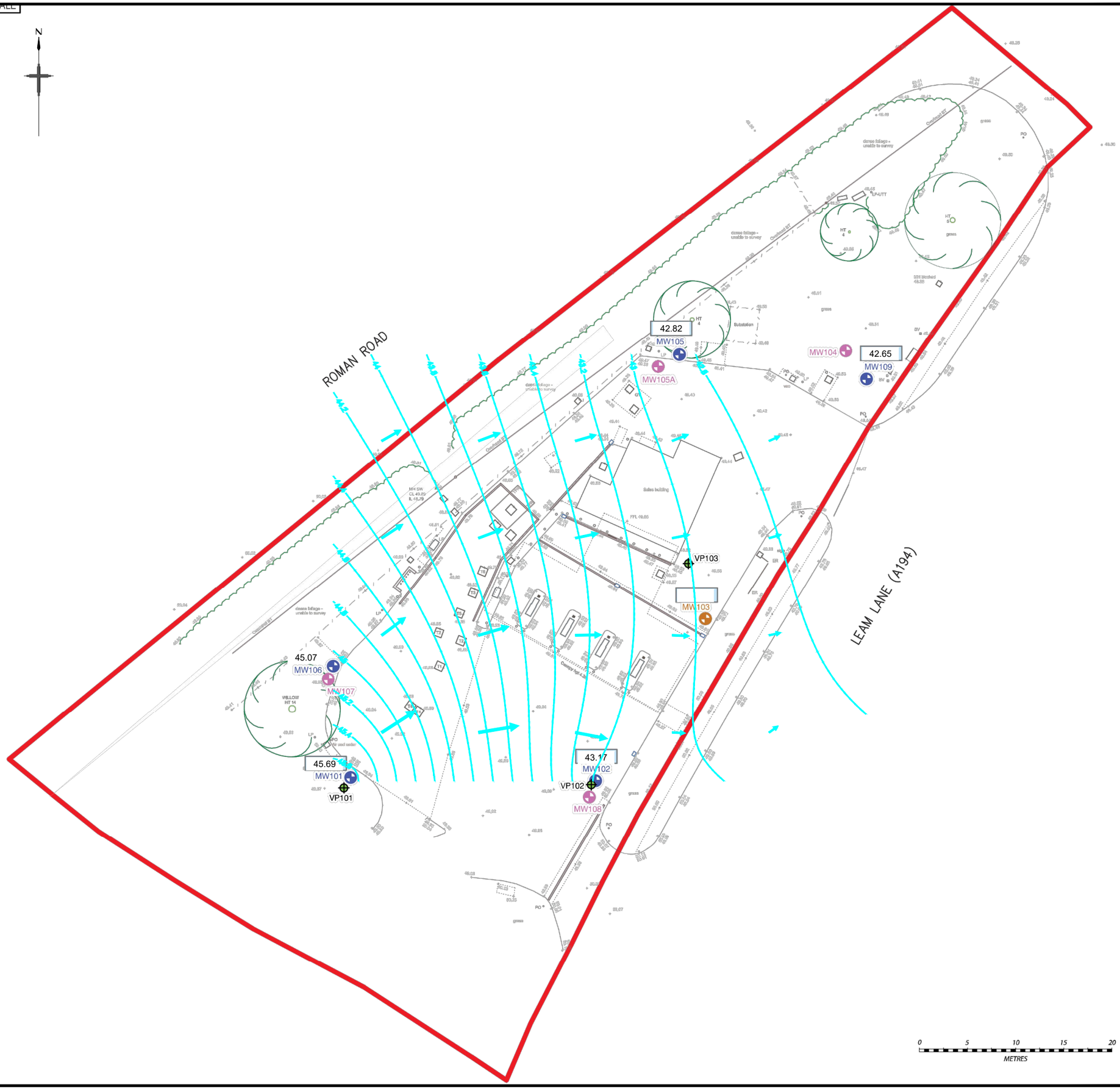
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00	MW	22.04.21	ML	22.04.21	ML	22.04.21

Dimensions	Scale	Original Size
m	1:25,000	A4

Project Number	Grid Ref	Scale Bar	Drawing Number
355390	NZ 311 615	0 250 500 750 1,000m	FIGURE 1

SCALE



ORIGINAL DRAWING

LEGEND:

- MW103 — Groundwater Well Installation (Superficial Perched Groundwater)
- MW101 — Groundwater Well Installation (Pennine Middle Coal Measures Formation)
- VP101 — Vapour Well Installation
- MW105A — Shallow Borehole to investigate superficial deposits, no installation
- 45.07 — Groundwater elevation (mAOD)
- mAOD — Metres Above Ordnance Datum

REV	DATE	DESCRIPTION	BY	CHD.	APR.
B	14.03.22	SECOND ISSUE	AS	ML	ML
A	03.08.21	FIRST ISSUE	HD	ML	ML

Dimensions	Projection	Scale	Orig Size
m		AS SHOWN	A3

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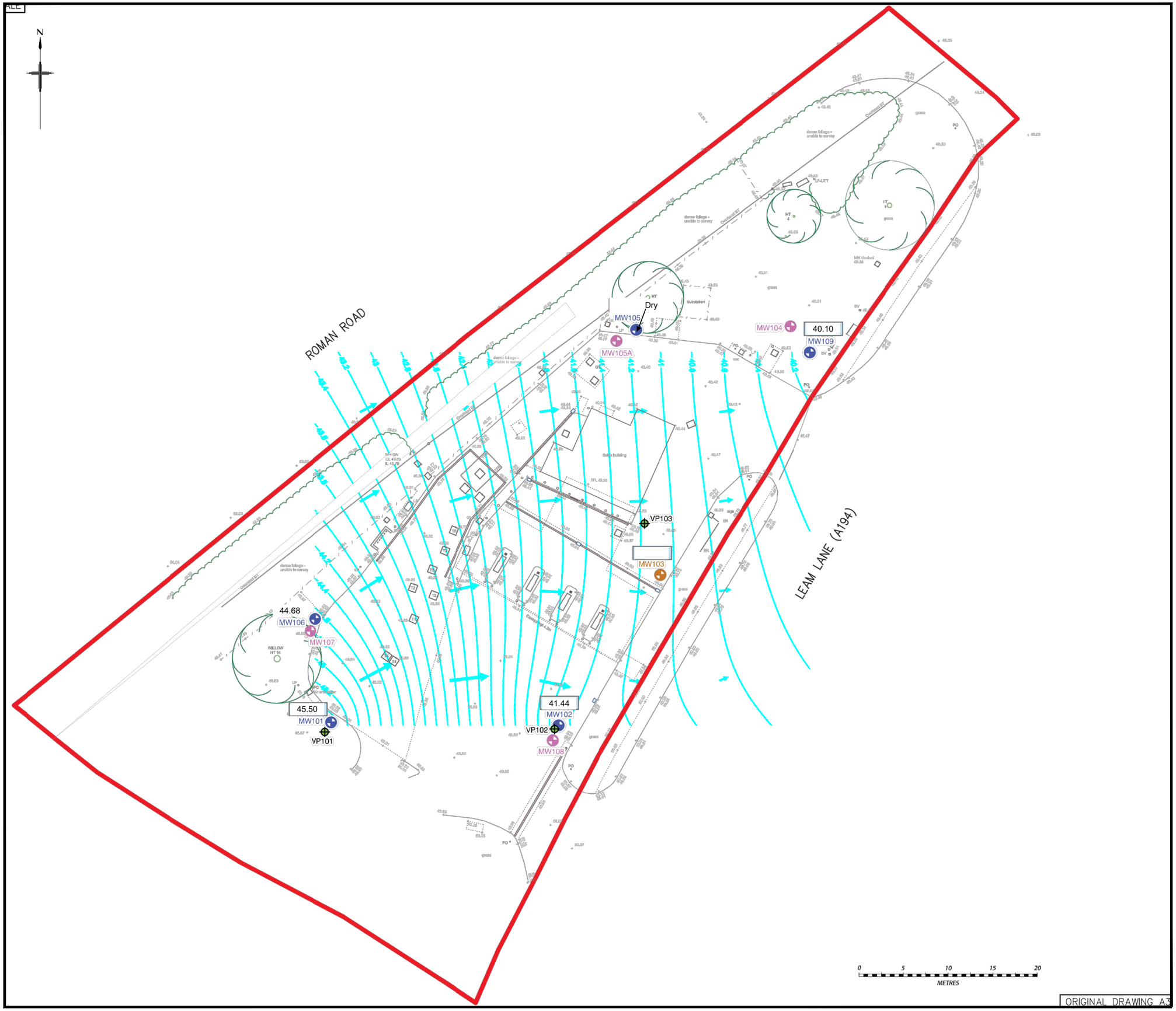
CLIENT
SHELL UK OIL PRODUCTS LIMITES

PROJECT
SHELL WHITEMARE POOL

TITLE
GROUNDWATER ELEVATION PLOT
10th DECEMBER 2019

JOB No.:	DRAWING FILE:
355390	355390-R01(00)D002aB

BY:	DATE:	CONTRACT NO.		REV:
AS	14.03.22		FIGURE 2a	B



LEGEND:

- MW103 — Groundwater Well Installation (Superficial Perched Groundwater)
- MW101 — Groundwater Well Installation (Pennine Middle Coal Measures Formation)
- VP101 — Vapour Well Installation
- MW105A — Shallow Borehole to investigate superficial deposits, no installation
- 45.07 — Groundwater elevation (mAOD)
- mAOD — Metres Above Ordnance Datum

REV	DATE	DESCRIPTION	BY	CHD.	APR.
B	14.03.22	SECOND ISSUE	AS	ML	ML
A	03.08.21	FIRST ISSUE	HD	ML	ML

Dimensions	Projection	Scale	Orig Size
m		AS SHOWN	A3

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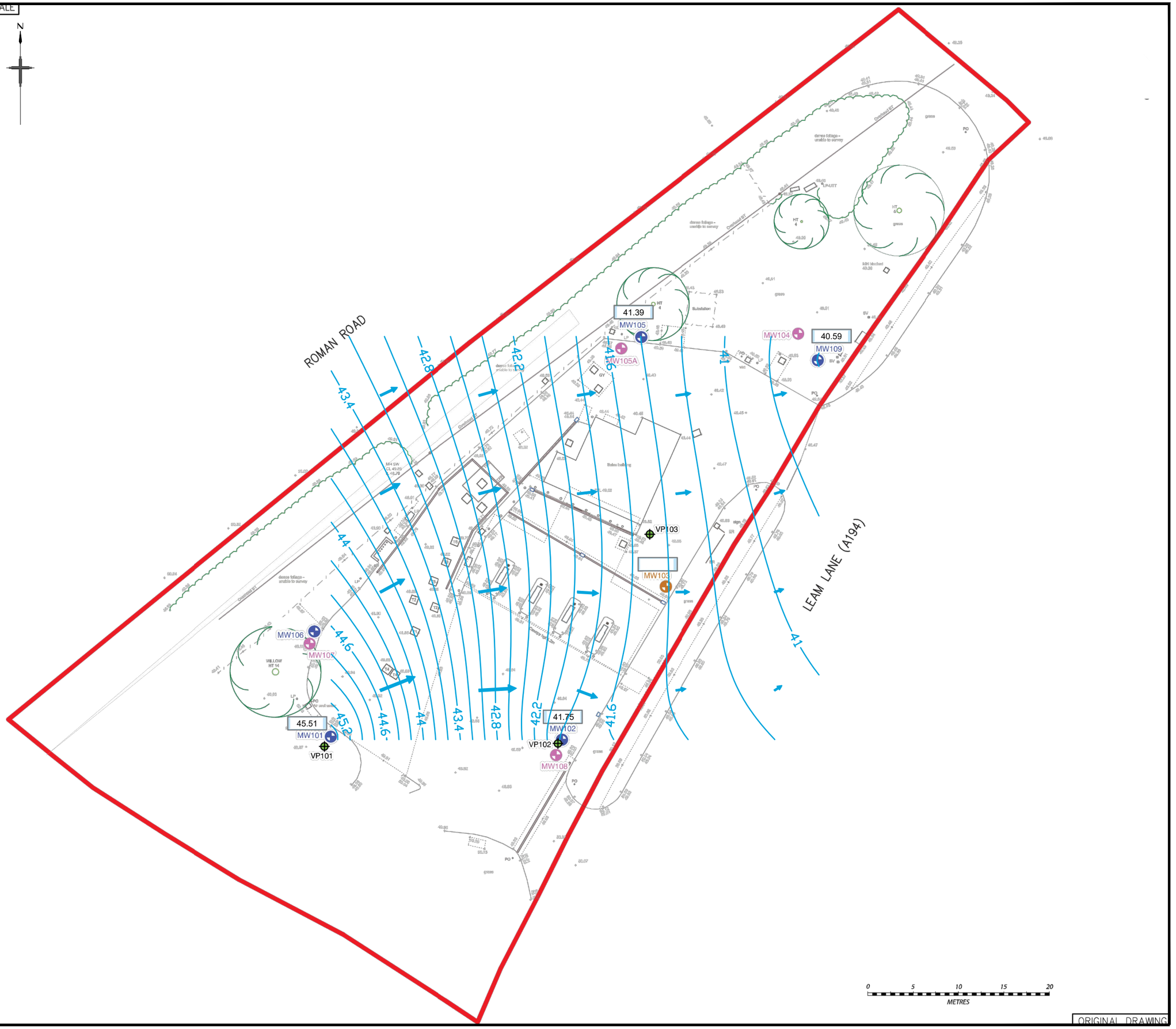
TITLE
GROUNDWATER ELEVATION PLOT
5th FEBRUAURY 2020

JOB No.:	DRAWING FILE:
355390	355390-R01(00)D002bB

BY:	DATE:	CONTRACT NO.		REV:
AS	14.03.22		FIGURE 2b	B

ORIGINAL DRAWING A3

SCALE



LEGEND:

- MW103 — Groundwater Well Installation (Superficial Perched Groundwater)
- MW101 — Groundwater Well Installation (Pennine Middle Coal Measures Formation)
- VP101 — Vapour Well Installation
- MW105A — Shallow Borehole to investigate superficial deposits, no installation
- 45.07 — Groundwater elevation (mAOD)
- mAOD — Metres Above Ordnance Datum
- Groundwater contours
- 41.6 — Groundwater level
- Anticipated direction water flow

REV	DATE	DESCRIPTION	BY	CHD.	APR.
C	15.03.22	THIRD ISSUE	BS	ML	ML
B	14.03.22	SECOND ISSUE	AS	ML	ML
A	03.08.21	FIRST ISSUE	HD	ML	ML

Dimensions	Projection	Scale	Orig Size
m		AS SHOWN	A3

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TITLE
GROUNDWATER ELEVATION PLOT
20th MARCH 2020

JOB No.:	DRAWING FILE:
355390	355390-R01(00)D002cC

BY:	DATE:	CONTRACT NO.		REV:
AS	14.03.22		FIGURE 2c	C

ORIGINAL DRAWING



LEGEND:

- MW103 — Groundwater Well Installation (Superficial Perched Groundwater)
- MW101 — Groundwater Well Installation (Pennine Middle Coal Measures Formation)
- VP101 — Vapour Well Installation
- MW105A — Shallow Borehole to investigate superficial deposits, no installation
- 45.07 — Groundwater elevation (mAOD)
- mAOD — Metres Above Ordnance Datum

REV	DATE	DESCRIPTION	BY	CHD.	APR.
B	14.03.22	SECOND ISSUE	AS	ML	ML
A	03.08.21	FIRST ISSUE	HD	ML	ML

Dimensions	Projection	Scale	Orig Size
m		AS SHOWN	A3

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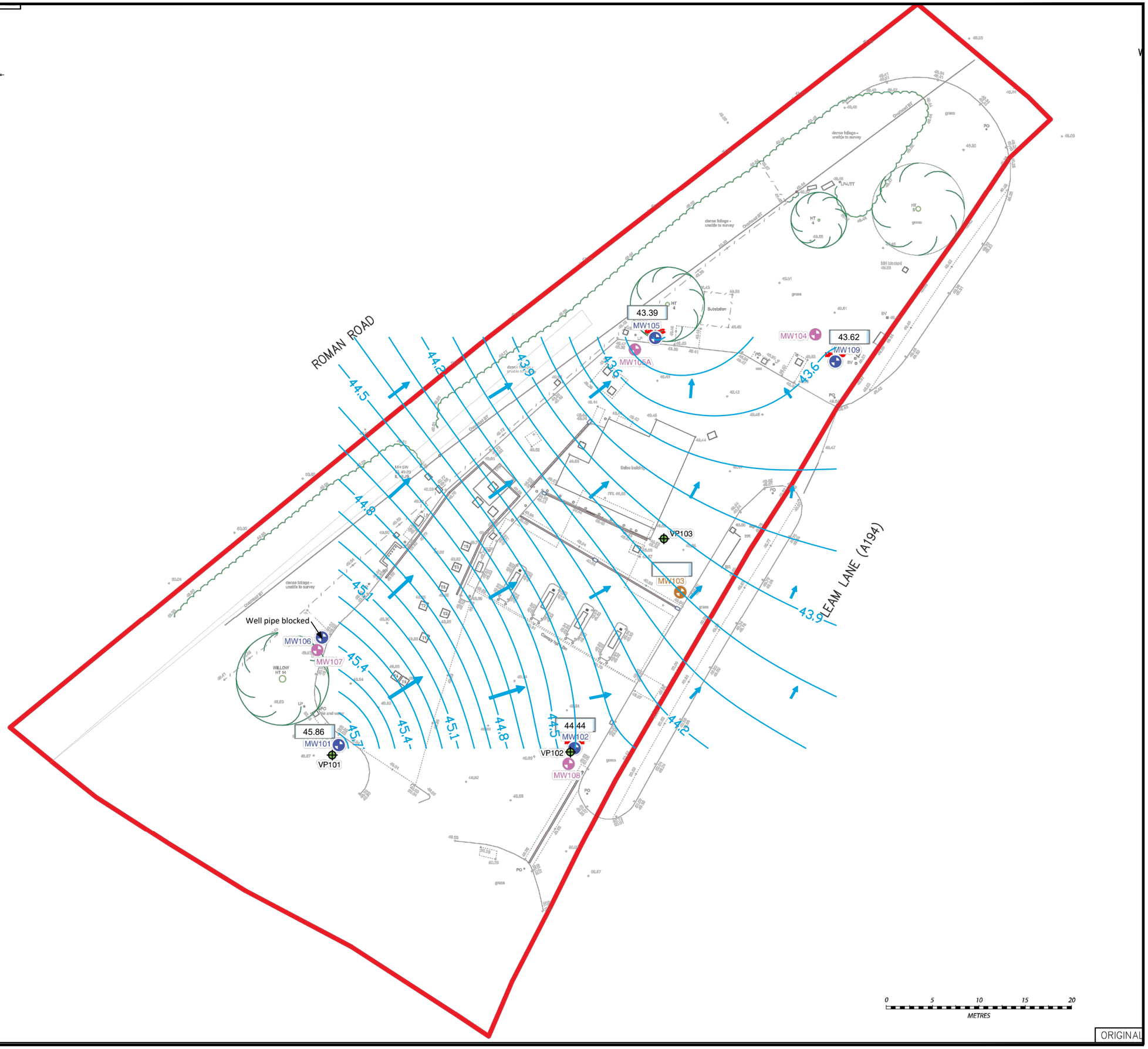
PROJECT
SHELL WHITEMARE POOL

TITLE
GROUNDWATER ELEVATION PLOT
26th MARCH 2020

JOB No.:	DRAWING FILE:
355390	355390-R01(00)D002dB

BY:	DATE:	CONTRACT NO.		REV:
AS	14.03.22		FIGURE 2d	B

ORIGINAL DRAWING A3



LEGEND:

- MW103 — Groundwater Well Installation (Superficial Perched Groundwater)
- MW101 — Groundwater Well Installation (Pennine Middle Coal Measures Formation)
- VP101 — Vapour Well Installation
- MW105A — Shallow Borehole to investigate superficial deposits, no installation
- 45.07 — Groundwater elevation (mAOD)
- mAOD — Metres Above Ordnance Datum
- Groundwater contours
- 41.6 — Groundwater level
- Anticipated direction water flow

REV	DATE	DESCRIPTION	BY	CHD.	APR.
C	15.03.22	THIRD ISSUE	BS	ML	ML
B	14.03.22	SECOND ISSUE	AS	ML	ML
A	03.08.21	FIRST ISSUE	HD	ML	ML

Dimensions	Projection	Scale	Orig Size
m		AS SHOWN	A3

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PROJECT
SHELL WHITEMARE POOL

TITLE
GROUNDWATER ELEVATION PLOT
24th FEBRUAURY 2021

JOB No.:	DRAWING FILE:
355390	355390-R01(00)D002eC

BY:	DATE:	CONTRACT NO.		REV:
AS	14.03.22		FIGURE 2e	C