Phase 2 Site Investigation Report

at Carrow Works, Bracondale, Norwich, Norfolk, NR1 2DD

for Unilever (UK) Ltd & Britvic Soft Drinks Ltd

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EXECUTIVE SUMMARY

The site is located on Bracondale in Norwich, NR1 2DD and comprises a large food products manufacturing facility and a conservation area encompassing a conference centre, canteen and the ruins of a 12th Century priory. The site is jointly owned and operated by Unilever (UK) Ltd and Britvic Soft Drinks (UK). The site extends to 16.9Ha and is located in a mixed land-use area comprising industrial, residential, commercial and open, undeveloped areas. The factories are scheduled to close at the end of 2019 and an assessment of the risks posed by contaminated land hazards is required (as part of other surveys and assessments) to determine the development potential of the land.

This report presents and discusses a Phase 2 preliminary site-wide intrusive investigation produced to accompany the recently issued Phase I Desk Study.

The intrusive investigation was designed to provide representative site wide coverage whilst targeting fuel, ingredient, product and waste storage. A total of 61 locations were excavated across 17 'Areas' comprising 53 windowless sampler boreholes and 8 hand excavated pits. The exploratory techniques were selected to minimise disruption to the ongoing site operations.

A geo-environmental risk assessment has been carried out. Concentrations of determinants were compared to 3 different sets of generic assessment criteria assuming a residential led mixed use redevelopment. Contamination testing of the soils identified fairly limited exceedances for metals (arsenic, cadmium, copper, lead and zinc), PAHs (naphthalene, phenanthrene and BaP), heavier fraction aromatic petroleum hydrocarbons and asbestos in made ground. No exceedances of any determinants were recorded in any natural soil sample.

Groundwater was not specifically targeted during this investigation as data is available from the on-site abstraction boreholes. These data will be analysed with the findings reported under separate cover. Two 'grab' samples of shallow perched water identified some minor exceedances of the environmental quality standards but no exceedances of the drinking water standards.

As there are currently no redevelopment plans available it was not possible to make an assessment of any remedial actions which may be required at this stage. However, should impacted made ground soils not be removed as part of the construction / redevelopment process then clean cover systems would likely be required in private gardens and areas of soft landscaping.

An assessment of the risk posed by land gas will need to be undertaken once development proposals have been produced. The results of this study indicate that the risk of vapour intrusion into buildings (outside of the known PCE plume area) is low.

Some further intrusive investigation will inevitably be required once redevelopment proposals are available and the factory has closed (which will relieve some of the constraints of investigating the site).

Further work will be required with respect to the known PCE plume in the north east of the site (an area consciously omitted from this current study). This work is necessary to understand the effects of switching off the abstractions at the site. A series of proposed steps to achieve this is provided in the recommendations section.

Signed:	 Dr Paul Adams BSc PhD MIEnvSc CSci
Countersigned:	 Tim Thorpe MSci FGS ARSM
Date:	19th September 2018
Revision:	Issue 1 - DRAFT

A INTRODUCTION

1 Authority

Leap Environmental Ltd (hereafter referred to as LEAP) has been appointed by Cushman and Wakefield Ltd (C&W) working on behalf of Unilever (UK) Ltd (Unilever) and Britvic Soft Drinks Ltd (Britvic) to undertake a Phase 2 Intrusive Site Investigation at a site referred to as Carrow Works, Bracondale, Norwich, Norfolk, NR1 2DD. The instruction was given via email by George Jolliffe of C&W.

2 Objective

LEAP understands that the site is currently jointly owned and occupied by Unilever and Britvic and is used for manufacturing purposes. Both parties have decided to cease production at the site with the factories scheduled to close by the end of 2019. C&W have been engaged by the land owners to assess the development potential and hence, the market value of the site. The Phase 2 Intrusive Site Investigation forms part of this assessment.

No details regarding a proposed redevelopment have been provided. It has therefore been assumed for the purposes of this report that a redevelopment (given the site's considerable size) would likely comprise a residential led mixed end use encompassing both high and low density housing, leisure facilities and public open space, commercial (both office and retail) and potentially light industrial land uses.

The objectives of this report are to:

- Provide information on the environmental quality of the ground present across the site;
- Assess the potential health and other environmental risks posed by the site to the proposed development and to other specifically identified receptors; and
- Assess the potential for offsite contamination to adversely affect the proposed development.

This report does not consider the geotechnical aspects of redeveloping the site.

3 Previous Studies

The site has been the subject of previous investigations by others. There is a known trichloroethylene contaminant plume present in the north eastern region of the site. Further information is provided in the desk study referenced below. Various phases of investigation

and modelling have been undertaken along with detailed discussion with the regulators. This report does not significantly address this issue as further works are proposed in this area which will be reported separately. This study focusses on the wider site as a whole.

LEAP has produced a Phase I Desk study which should be read in conjunction with this report:

- Phase 1 Desk Study, Site Reconnaissance Report. LEAP Environmental Ltd. Report Ref: LPO1671/DS, dated 13th July 2018.

4 Scope of Works

4.1 Intrusive Investigation Scope

The Phase II work comprises intrusive investigation and laboratory analysis. The results are used to validate and/or update the initial site conceptual model. This phase of site investigation comprised the following tasks:

- 53 No. circa 5m deep windowless boreholes drilled with a tracked rig;
- 8 No. 1m deep boreholes drilled using hand auger boring apparatus;
- Soil sampling and logging; and
- Chemical Laboratory testing.

The intrusive works were completed by contractors who have been scrutinised and are on LEAP's approved contractor list. The windowless sampling and hand pitting were carried out by Oakland Site Investigation Limited under the full-time supervision of LEAP engineers.

Selected samples of soil and two samples of groundwater were scheduled for laboratory testing for a wide range of potential contaminants including metals, non-metals, polyaromatic and petroleum hydrocarbons and volatile organic compounds. The laboratory testing has been carried out by I2 Laboratory Ltd at their facility in Watford.

The final stage in the geoenvironmental assessment comprises a quantitative risk assessment and revision of the preliminary Conceptual Site Model. Recommendations for further work have been provided, based on various development assumptions. The risk assessment has been carried out in accordance with UK industry standards and in particular in accordance with CLR11[1] and BS10175:2011+A1:2013.

[1] Environment Agency, 2004. Model Procedures for the management of land contamination. Contaminated Land Report 11.

5 Limitations

This report has been prepared by Leap Environmental Ltd on the basis of information received from a variety of sources which Leap Environmental Ltd believes to be accurate. Nevertheless, Leap Environmental Ltd cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

Leap Environmental Ltd has used all reasonable skill, care and diligence in the design and execution of this report, taking into account the manpower and resources devoted to it in agreement with the Client. Although every reasonable effort has been made to obtain all relevant information, all potential contamination, environmental constraints or liabilities associated with the site may not necessarily have been revealed.

The conclusions reached in this report are necessarily restricted to those which can be determined from the information consulted and may be subject to amendment in the light of additional information becoming available. These conclusions may not be appropriate for alternative schemes.

This report is confidential to the Client and Leap Environmental Ltd accepts no responsibility whatsoever to third parties to whom this report, or any part thereof, is made known, unless formally agreed by Leap Environmental Ltd beforehand. Any such party relies upon the report at their own risk.

Full details of the limitations are provided in Appendix A.

B SUMMARY PHASE I

6 Environmental Setting

This Section presents a brief introduction to the site from an environmental standpoint. A more detailed description is provided within the Phase I desk study report.

6.1 Site Location and Description

The site is located at Carrow Works, Bracondale, Norwich, Norfolk, NR1 2DD. The site's approximate National Grid Reference at the site entrance is TG242072. The site lies at an estimated elevation of 5-8m Above Ordnance Datum (mAOD) in the main site area and 10-17 mAOD in the conservation area. The site extends to approximately 16.9 Ha.

6.1.1 General Description and Boundaries

The current site layout is shown in drawing SITEB10F, Appendix B. Photographs taken during the walkover are included within the Phase I desk study report (Appendix E therein).

The site has a dedicated entrance off a roundabout on Bracondale (the A1054). The site is located south of the River Wensum, circa 1Km south of Norwich City Centre. To the west is the primarily residential area of Lakenham and to the east (beyond the immediately adjacent railway line and aggregate yard) are open fields with drainage channels and Whitlingham Country Park. To the south east of the site is Norwich Fire Station. To the south beyond the road junction are properties associated with Norfolk County Council and an industrial estate.

The site comprises two areas, namely the main works area (northern, central and eastern site regions) and the conservation area (in the central and south western regions).

The main works area comprises numerous large warehouse, manufacturing and office buildings of varying age and construction due to the long 150 year history of the site. The site has dedicated vehicle and pedestrian access routes. External to the main buildings, there are smaller structures housing water supply boreholes (discussed further in later sections), water treatment plant, process chemicals and electrical infrastructure. There are numerous storage containers referred to as roto plas containers in storage yards (most belonging to Unilever and containing processed mint).

The conservation area encompasses the ruins of a 12th Century priory and Carrow Abbey. Abbey Conference Centre is located in the northern part of the conservation area and encompasses the original house. Car parking facilities, the former technical (R&D) centre, a canteen, gardens and groundmen's facilities are also present.

The site is fairly flat with a low point in the northeast and a highpoint in the conservation area. The only significant change of levels (where a bank is present) is via steps from the region

where BH F / building 256 is located to the conservation area. An engineered drainage system and sprinkler system (below ground) operates across the site.

Groundcover is exclusively concrete or asphalt in the factory area. In the conservation area there are areas of soft landscaping comprising mature trees, garden areas / borders, grass and shingle.

6.2 Geology

The geology of the site has been ascertained by reference to the BGS website (www.bgs.ac.uk) and the Envirocheck report. The superficial deposits across the majority of the site are indicated to comprise River Terrace Deposits. In the north eastern corner of the site the superficial geology is indicated to comprise Alluvium. No superficial geology is indicated to be present on the western boundary region of the site. The solid / bedrock geology is mapped as Chalk. Further information describing the geology (including that taken from logs relating to nearby boreholes) is presented in the Phase I desk study report.

6.3 Hydrogeology

The hydrogeology of the site has been ascertained from the Envirocheck data report. The source of the data is reported to be the Environment Agency groundwater vulnerability mapping.

The Alluvium and River Terrace Deposits are reported to be a secondary (A) aquifers. The Chalk is designated as a principal aquifer with high groundwater vulnerability. The entire site and surrounding area is located with a groundwater source protection zone (SPZ) 1 (Inner Protection Zone defined as a travel time of less than 50 days to a drinking water abstraction well).

The Envirocheck lists 148 groundwater abstractions on site. These refer to multiple records at 6 No. abstraction points ('Bore' A-F).

There is 1 further active groundwater abstraction within 250m of the site held by Norwich City Football Club (182m northwest) for spray irrigation.

The Envirocheck report (BGS records) indicates that the north eastern region of the site has potential for groundwater flooding to occur at surface. Significant parts of the north, north western and eastern regions of the site have potential for groundwater flooding of property situated below ground level to occur.

The local groundwater flow would be anticipated to be to the north towards the River Wensum. The regional groundwater flow would be anticipated to be towards the east as the River Wensum flows into the River Yare which then flows broadly east before discharging into the sea at Gorleston-on-Sea, Great Yarmouth. It is noteworthy, that the abstractions on

site are likely to significantly influence the local groundwater flow given the high volumes being abstracted.

6.4 Hydrology

There are no surface water features indicated within the site. The River Wensum runs adjacent to the entire northern boundary. An on-site surface water abstraction (from the river) is listed within the Envirocheck report. There are 4 additional surface water abstractions (1 from the River Wensum and 3 from the River Yare) within 250m of the site. The water is reportedly used for cooling, general/process washing and industrial processing).

The Envirocheck report indicates that there is 1 active discharge consent on-site (with 2 revoked licences relating to the same location). The license relates to the discharge of process water to the River Wensum. There are a further 22 records of discharge consents within 250m of the site. Circa 4 or 5 appear active and all relate to emergency discharge of storm or sewage water into the local watercourses.

C PHASE II - INTRUSIVE INVESTIGATION

7 Investigation Rationale

A total of 61 trial holes were excavated across the site. These included 53 windowless sampler boreholes to depths of between circa 2m and 5m and 8 hand dug pits to circa 1m.

The trial holes were located to give general coverage, taking into consideration a potential mixed use re-development and the potential geoenvironmental risks/hazards highlighted by the CSM in accordance with BS10175. In particular, trial holes were targeted on the location of current and historical fuel and chemical storage infrastructure (above and below ground tanks, silos etc.).

Access was not considered necessary within buildings as the clients advised that the vast majority of fuel and chemical storage is located outdoors and the main focus of processes within the buildings comprises dilution of concentrated products and packaging.

Deeper boreholes to specifically target groundwater were not installed during this investigation as samples are regularly collected from the various abstraction boreholes across the site in accordance with the requirements of the environmental permit. These data will be analysed as part of the planned additional works. Further boreholes may be required at a later date.

Windowless sampling and hand pitting was selected as trial pits were concluded to be prohibitively obstructive to ongoing site operations.

The investigation rationale for the trial holes is summarised below:

Table 1 Rationale for Investigation Locations

Trial Hole/Test Location	Rationale
Area 1 (Buildings 259 and 39F)	
WS34 and 35	Adjacent to the chemical and flammable goods store. Potentially on the edge of the PCE plume area.
WS36-39	Adjacent to the raw ingredient silos for the mint / wet products plant. Potentially on the edge of the PCE plume area.
Areas 2 and 3 (Eastern site boundary)	
WS53-55	General site coverage
Area 4 (Building 258)	
WS50-52	Coverage of the diesel above ground storage tanks and waste storage area

Area 5 (Lorry park)	
WS44 and 45	General site coverage
Area 6 (West of buildings 224/2 to 224/4)	
WS47-49	Coverage of an area where historical maps show tanks were once located
Area 7 (Building 213)	
WS40-41	Coverage of the former R&D centre (targeting the outgoing drainage)
WS42 and 43	Coverage of an electrical substation. EXCAVATED AS HAND PITS DUE TO LACK OF ACCESS
Area 8 (Conservation area)	
HP3-6	Coverage of an area of dilapidated greenhouses (possible asbestos rope)
Area 9 (Buildings 107 and 252)	
WS29-32	Coverage of the boiler house, chlorination plant and diesel storage areas
Area 10 (Buildings 107, 256 and 261)	
WS23-27 and 27A	Coverage of the boiler house and water treatment plant
Area 11 (South of building 254)	
WS15 and 17	General site coverage
Area 12 (Southwest of building 254)	
WS7, 8, 10, 11, 11A-14	Coverage of the pH balancing plant and below ground strong waste tank
Area 13 (Buildings 212A and B)	
WS1-3	Coverage of the former fire station
Area 14 (Building 207)	
WS4, 5 and 9	Coverage of former vehicle storage and maintenance area where below ground fuel tanks and former fuel pumps were anticipated
Area 15 (Buildings 7A, 8A and 209)	
WS16	Coverage of a former substation
HP1	Coverage within an accessible building area where a generator was once located
WS18 and 19	Coverage of areas where sewers are known to have historically leaked and been repaired
WS20	Coverage of the above ground strong waste compound

Area 16 (Building 204)	
HP2	Coverage of an area where sewers are known to have historically leaked and been repaired
WS21	Coverage of the above ground strong waste compound
WS22	General site coverage
Area 17 (North of building 201 alongside the river)	
WS28 and 33	General site coverage

WS6 and 46 were omitted due to administrative numbering error

The site investigation locations are shown on Figures 2-19, Appendix B.

8 Site Work

8.1 Date and Weather Conditions

The intrusive investigations were undertaken in a single phase between 20th and 30th August 2018 (excluding the weekend). At the time of the investigations, the weather was primarily warm and dry with some occasional intermittent rain showers.

8.2 Site Work Methods

8.2.1 Borehole Drilling

Boreholes were drilled using a windowless sampler rig. The boreholes were excavated at 110mm diameter, reducing the diameter with depth. Borehole logs are provided in Appendix D.

8.2.2 Hand Pitting

Hand pits were excavated using hand tools/ a hand auger at circa 150mm diameter. Spoil was placed on plastic sheeting to prevent cross contamination and was reinstated in reverse order. All windowless boreholes were initiated with a 1.2m hand pit for the purposes of service avoidance.

8.2.3 Soil Logging and Sampling

Soil samples were recovered from the boreholes and trial pits for field screening, logging and sampling. Boreholes were logged in general accordance with the requirements of BS 5930:2015[2] and BS EN ISO 14688[3].

Visual and olfactory evidence of contamination was noted if encountered. These observations were used to aid scheduling of samples for chemical laboratory analyses and are included on the borehole logs.

Samples were collected by hand (using dedicated nitrile gloves for each sampling location). Samples were placed into laboratory supplied sampling containers, specific to the type of analyses required.

All sample containers were sealed and labelled with a unique location identity, depth and date of sampling.

8.2.4 Monitoring Well Installation

No monitoring wells were installed during this investigation.

8.3 Ground Gas and Groundwater Monitoring

8.3.1 Surface water sampling

No surface water monitoring or sampling was undertaken during this investigation.

8.3.2 Groundwater sampling

Two 'grab samples' of perched groundwater were recovered during windowless sampling (WS24 and 27A).

Samples were recovered in glass amber bottles and vials and placed in cool boxes for transport to i2 Laboratory Ltd for laboratory analysis.

8.3.3 Ground gas monitoring

No ground gas monitoring was undertaken during this investigation.

8.4 Laboratory Analysis

8.4.1 Chemical Soil Analysis

Selected samples of soil have been subjected to laboratory testing. Sampling techniques and storage have been undertaken as per BS 10175:2011+A1:2013 Code of Practice for Investigation of Potentially Contaminated Sites. The laboratory testing has been carried out

[2] BS5930:2015 Code of Practice for Ground Investigation

[3] BS EN ISO 14688 Parts 1-2 Geotechnical Investigation and Testing. Identification and classification of soil

by i2 Laboratory Ltd at its laboratories in Watford. Where available, the tests procedures are UKAS and MCERTS accredited.

The following analyses were completed on selected samples:-

- LEAP standard soil suite (metals, speciated PAHs, pH, total organic carbon, asbestos)
- Petroleum Hydrocarbons (including BTEX)
- Volatile Organic Compounds
- Semi Volatile Organic Compounds
- Asbestos Quantification
- Flame retardants (PFOS & PFAS) (WS1-3 only)

The full laboratory test results are presented in Appendix E.

8.4.2 Chemical Water Analysis

Two samples of perched groundwater have been subjected to laboratory testing. Sampling techniques and storage have been undertaken as per BS 10175:2011+A1:2013 Code of Practice for Investigation of Potentially Contaminated Sites. The laboratory testing has been carried out by i2 Laboratory Ltd at its laboratories in Watford. Where available, the tests procedures are UKAS and MCERTS accredited.

The following analyses were completed on selected samples:-

- LEAP standard water suite (metals, speciated PAHs, sulphate, sulphide, cyanide and phenol)
- Petroleum Hydrocarbons
- Volatile Organic Compounds
- Semi Volatile Organic Compounds

The full laboratory test results are presented in Appendix E.

9 Ground Conditions

The ground conditions are described in detail in the logs attached in Appendix D. In summary the soil conditions were as follows:

Table 2: Summary of soils encountered

Depth From (m)	Depth To (m)	Soil Type	Description
0	0.1 / 1.2	**Hardstanding**	Hardstanding comprising either CONCRETE, BLACKTOP or BRICK PAVING
0	0.15 / 1.2	**MADE GROUND / TOPSOIL**	MADE GROUND: Brown slightly clayey gravelly fine sand Topsoil with fine to coarse, angular to rounded flint, natural stone and brick gravel with rootlets.
0 / 1.2	0.3 / 4.0	**MADE GROUND**	MADE GROUND varying between: Brown to grey slightly clayey gravelly medium to coarse SAND with fine to coarse, angular to rounded flint, concrete and rare blacktop and brick gravel. Brown sandy gravelly SILT with fine to coarse, angular to rounded flint, natural stone, brick and concrete gravel with occasional rootlets Soft grey to brown with occasional white speckles sandy silty gravelly CLAY with fine to coarse, angular to rounded flint, natural stone, chalk, concrete and brick gravel. Dark brown to grey to black sandy clayey GRAVEL of fine to coarse, angular to rounded flint, natural stone, chalk, concrete, blacktop and brick.
1 / 1.8	1.2 / 3.8	**MADE GROUND**	MADE GROUND: Off-white to white structureless CHALK, recovered as putty chalk with fine to coarse, angular to sub-angular chalk, flint and occasional brick gravel with patches of pale brown sandy infill. (possible re-worked chalk).
0.3 / 4.5	0.8 / 5	**SAND**	Brown to grey silty slightly clayey gravelly medium to coarse SAND with fine to coarse, angular to rounded flint and chalk gravel with fine shell fragments and organic material.

0.45 / 1	1 / 2	**CLAY**	Brown and white speckled gravelly CLAY with fine to medium chalk and fine to medium, angular to rounded flint gravel.
2.7 / 4.6	3 / 5	**GRAVEL**	Off-white to grey clayey sandy GRAVEL of fine to coarse, angular to rounded flint and occasional chalk gravel.
1.65 / 3.4	3.5 / 4.6	**PEAT**	Dark brown fibrous clayey sandy PEAT with organic fragments with an organic odour noted in the soil.
0.3 / 4.75	2.7 / 5	**CHALK**	Off-white to white structureless CHALK, recovered as putty chalk with fine to coarse, angular to sub-angular chalk and rare angular to rounded flint gravel with patches of pale brown sandy infill.

In general ground conditions were found to comprise hardstanding over a varying thickness of made ground over Alluvium over Chalk. Concrete was particularly thick in Area 12, in proximity to the storage tanks. Topsoil was only found in Area 8, where the ground surface was softstanding.

Made Ground varied across the site in both thickness and composition, however predominantly comprised reworked natural soils with some fragments of brick and concrete. Made ground was relatively thin in Areas 10 and 14, and very silty made ground only occurred in the far south of the site, in Area 4.

Where Alluvium was encountered it was found predominantly as a clayey gravelly sand, with occasional clay bands (WS22, WS23 and WS25), gravel bands (WS4, WS35 and WS39) and peat bands (WS35, WS37, WS38 and WS39). Peat soils were exclusively present in the northeast of the site, in Area 1.

Chalk was encountered directly beneath the made ground at a number of locations (WS1a, WS2, WS3, WS4, WS5, WS8, WS10, WS14, WS15, WS16, WS17, WS23, WS25, WS29, WS30 and WS32), whilst in others there was varying thickness of Alluvial soil above it, or it was not encountered within the depth of exploration (WS18, WS20, WS21, WS22, WS36, WS37, WS38, WS44, WS45, WS49, WS50, WS51, WS52 and WS54).

In Area 12 it was not possible to penetrate through the made ground into the underlying natural soils around the below ground tanks due to concrete obstructions.

9.1.1 Groundwater

Confirmed groundwater strikes were recorded in the following trial holes. Other instances where moist or wet soils were recovered are shown on the borehole logs.

Table 3: Groundwater Strikes

Trial Hole	Date of water strike	Depth to Groundwater strike (mbGL)	Comments
WS23	21/08/2018	4.0	
WS24	21/08/2018	0.8	Water is grey and black with no distinct odour.
WS25	21/08/2018	3.2	
WS29	22/08/2018	4.2	
WS32	22/08/2018	3.5	Water is pale brown.
WS30	22/08/2018	4.5	
WS17	22/08/2018	4.5	
WS27a	22/08/2018	0.55	Water sample taken at 0.50m.
WS19	23/08/2018	4.0	
WS39	24/08/2018	1.5-2.0	Depth of water rose to 0.97m after 20 minutes.
WS37	24/08/2018	3.9	Depth of water rose to 2.05m after 20 minutes.
WS36	24/08/2018	3.0	Depth of water rose to 1.8m after 20 minutes.
WS38	24/08/2018	3.0	Depth of water rose to 2.0m after 20 minutes.
WS35	28/08/2018	3.0	
WS28	29/08/2018	4.0	
WS22	30/08/2018	4.2	
WS20	30/08/2018	4.2	

9.1.2 Visual and Olfactory Evidence of Contamination

Visual and olfactory evidence of contamination noted during the investigation works is summarised in the following table.

Table 4: Summary of Visual and Olfactory Evidence

Hole ID	Depth (m)	Olfactory Evidence	Visual Evidence
WS1	0.05-0.6	_	Sewage odour
WS1A	0.05-0.2	_	Sewage odour
	~1.6	Mild hydrocarbon odour	_
WS8 & WS15	4.2 & 4.8-5.0	Mild hydrocarbon odour	Potential blue / black discolouration
WS11	0.17-0.67	_	Black (possibly ashy) sand*
	0.67-1.0	_	Clinker
	3.15-3.4	Mild strong waste odour	_
WS14	0.15-0.6	_	Ashy inclusions
WS19	1.2-1.4	Hydrocarbon odour	_
	1.4-1.9		Patchy black staining
WS21	0.15-0.9	Mild hydrocarbon / organic odour	_
WS24	0.25-0.62	_	Potential grey and black discolouration
	0.8	_	Black discoloration to groundwater
WS28	1.1-2.9	_	Dark brown ashy sand
	3.8-4.5	_	Black patches in chalk
WS31	0.2-1.15	_	Clinker
WS35	1.4-1.8	_	Black ashy sand
	2.4-2.7	Mild hydrocarbon / organic odour	_
	2.7-3.0	_	Clinker
WS36	1.10	_	Black, ashy sand
WS37	0.4-0.9	_	Ash and clinker
WS38	0.8-1.1	_	Charcoal
	1.2-1.55	_	Clinker
WS39	0.41-1.25	_	Clinker
WS51	0.4-1.5	_	Patchy black gravels and clinker
HP2	0.6	Mild hydrocarbon odour	Inclusions of black glass / hard plastic-like material
HP4 / HP5	0.0-0.5 / 0.0-0.6	_	Ashy inclusions

*also present at similar depths in WS12 and 13.

D GEO-ENVIRONMENTAL APPRAISAL

10 Conceptual Site Model

The preliminary conceptual site model (CSM) has identified a number of potential contaminant linkages.

Potential on and off-site sources of contamination capable of impacting the site identified in the preliminary CSM are summarised in Tables 5 and 6 respectively:

Table 5: Onsite sources of contamination

Source	Contaminants of Concern
Above ground and underground fuel tanks storing fuel oil and waste oils	Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAH), heavy metals
Storage and use of chemicals associated with cleaning/disinfection/sterilisation – detergents, surfactants, organic solvents	Volatile Organic Compounds (VOC) including PCE and its breakdown products, Semi-volatile Organic Compounds (SVOC), acids and alkalis
Storage of process raw materials	Acids, alkalis, oils, dyes (VOCs and SVOCs)
Former railway sidings	PAH, heavy metals, oils and greases
Former timber yard and saw mills	Wood preservatives – PAH, phenol and creosols
Buildings and service ducts constructed prior to 2000	Asbestos
Made Ground associated with installation and construction of various buildings	PAH, asbestos and heavy metals
Electrical Substations	Polychlorinated Biphenyls (PCBs), mineral oil
Former technical / R&D centre (laboratory)	Solvents
Coolant	Ethylene glycol

Table 6: Off-site sources of contamination

Source and distance	Contaminants of Concern
Railway adjacent to the east of the site	PAH, heavy metals, oils and greases
Railway storage depot	Metallic powders, undisclosed chemicals in drums
Former sheet metals workers and asphalt / macadam suppliers 16m (south) of the site	Heavy metals, PAH
Former timber works and identified works circa 100m (east) of the site	Wood preservatives – PAH, phenol and creosols
Active petrol filling station 258m northwest of the site.	TPH, PAH, MTBE, BTEX and heavy metals (in groundwater)

10.1 Receptors

Potential receptors identified within the preliminary CSM comprise the following:

- Current and future users of the site
- Construction workers
- Groundwater (secondary (A) aquifers – River Terrace Deposits and Alluvium and underlying principal aquifer - Chalk)
- Surface Water – Rivers Wensum and Yare
- Material construction of buildings and infrastructure
- Neighbouring properties and occupants

The preliminary CSM is presented in full in the Appendix (D) of the Phase I desk study.

10.2 Preliminary Assessment of Risk

The preliminary CSM assessed the following pollutant linkages as moderate risk:

- Ingestion of hydrocarbon/solvent impacted soil by future site users;
- Ingestion of hydrocarbon/solvent impacted household and fugitive soil dust by future site users;
- Inhalation of soil-derived vapours within buildings by current and future site users; and
- Inhalation of land gases within buildings by current and future site users.

The following pollutant linkages are rated as high:

- Intergranular flow of free-phase contamination and migration into groundwater; and
- Inhalation of asbestos fibres by construction / maintenance workers.

11 Assessment Criteria

11.1 Human Health Assessment Criteria

The generic quantitative risk assessment (GQRA) for human health compares the analytical results from the current investigation to Generic Assessment Criteria (GAC). These were selected using the following rationale and assumptions.

Defra and the EA have published a limited number of Soil Guideline Values (SGVs)[4] that represent minimal chronic risk to human health. CL:AIRE has published a limited number of Category Four Screening Levels (C4SLs)[5] which represent a low but still strongly precautionary level of chronic risk to human health. Both the SGVs and C4SLs have both been derived for a Soil Organic Matter (SOM) content of 6%, which is not always representative of the low SOM that are encountered within Made Ground on brownfield sites.

LQM responded to the demand for a more comprehensive set of screening values for a wider range of SOM and produced Suitable for Use Levels (S4ULs)[6] which are a hybrid of SGVs and C4SLs. The S4ULs have been endorsed by the Chartered Institute of Environmental Health (CIEH).

LEAP uses C4SLs where they are available as generic assessment criteria to quantitatively assess the potential chronic risks to human health. Where C4SLs are not available, the S4ULs are used. It is noted that S4ULs are not equivalent to C4SLs in all their exposure assumptions but are generally more conservative in their assumptions. For benzene and benzo(a)pyrene), LEAP has calculated equivalent C4SLs for 1% and 2.5% SOM. This does not affect the inorganic contaminants.

In accordance with current Public Health England (PHE) guidance[7], the assessment of PAHs has been carried out using a surrogate marker approach, whereby the assessment of risk from benzo(a)pyrene also captures potential risks from other carcinogenic PAHs that may be present. The alternative S4ULs for PAHs using the Toxic Equivalent Factor (TEF) approach have not been used because this approach is likely to under predict the true carcinogenicity of PAHs and is not advocated by PHE. The threshold PAHs have been assessed individually.

Sets of GACs have been generated for SOMs of 1%, 2.5% and 6%. In this case, TOC in the Made Ground samples that were analysed averaged at 1.41%. Using the conversion of SOM = TOC x 1.72, this equates to a SOM of 2.43%. 2.5% SOM was therefore considered to be appropriate.

For some contaminants of concern, direct contact will be the dominant pathway for exposure. In order to support with development options, human exposure to all unsaturated soils, irrespective of depth, was assumed possible for the purpose of this assessment. This will

[4] Environment Agency Science Report SC050021 series.

[5] CL:AIRE Final Project Report. SP1010 – Development of Category 4 Screening Levels for assessment of land affected by contamination. CL:AIRE, December 2013

[6] The LQM/CIEH S4ULs for Human Health Risk Assessment, Nathaniel P et al, 2015. Copyright Land Quality Management Ltd, reproduced with permission: Publication Number S4UL3509

[7] HPA Contaminated Land Information Sheet. Risk Assessment Approaches for Polycyclic Aromatic Hydrocarbons (PAHs). Public Health England, 2017.

maximise the information available to the design team on the suitability of all unsaturated material and can support with their materials management options.

As a mixed use re-development has been assumed, the laboratory data has been screened against residential with consumption of home-grown produce, public open space (residential) and commercial GACs.

Potential risks to human health from soil gases are assessed in Section 14.3.

11.1.1 Statistical Assessment

Statistical assessment is only valid when the samples can be considered to be fully representative of the 'average' conditions across the site as a whole. As the vast majority of sample locations were targeted in this investigation, statistical analysis is not considered appropriate for this dataset and hence, the data has been compared directly against the GACs.

11.2 Groundwater and Surface Water Assessment Criteria

The generic controlled waters risk assessment was conducted in accordance with the principles of EA '*Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination'* 2006 (EA 2006) and the 'prevent and limit' approach of the Water Framework Directive (2000/60.EC). Generic controlled waters risk assessments compare directly measured concentrations with standard assessment criteria.

In this case a Level 2 assessment was undertaken which evaluates the concentrations of chemicals within the saturated zone immediately underlying a source area i.e. taking dilution and attenuation into account, in this case groundwater analysis.

Appropriate Water Quality Standards (WQS) are selected based on both a hierarchy of relevance to England and Wales and the receptor. In this case, the key controlled water receptors identified in the CSM were the principal chalk aquifer and the River Wensum and so the following hierarchy of WQS were considered to be appropriate:

Aquifer

- UK Drinking Water Quality Standards (DWS) from *The Water Supply (Water Quality) Regulations* 2016 (England).
- World Health Organisation *Guidelines for Drinking Water Quality*, Fourth Edition, Volume 1, (2011).
- World Health Organisation *Petroleum Products in Drinking Water* (2008).

Surface Water

- Environmental Quality Standards (EQS) from *The Water Framework Directive (Standards and Classification) Directions (England and Wales)* 2015.

11.3 Land Gas Assessment Criteria

By way of a preliminary risk assessment we have adopted "the pragmatic approach to ground gas risk assessment" as presented by Card et al 2012[8] . This approach considers the Total Organic Content (TOC) of the made ground as well as the age and depth of the fill.

12 Analytical Test Results – Soils

12.1 Metals and Non-metals

The soil samples have been subdivided into 2 populations representing made ground (84 samples) and natural soils (35 samples). NOTE: Not all samples were tested for all determinants.

The test results for each population have been subjected to screening against the 3 selected land use criteria. The exceedances recorded in made ground are tabulated below.

There were no exceedances in natural soils.

[8] Card G., Wilson S, Mortimer S. 2012. A pragmatic approach to ground gas risk assessment. CL:AiRE Research Bulletin RB17.

Table 7: Summary of metal and non-metal exceedances within made ground (70 samples)

Determinant	Average Concentration [mg/kg]	Maximum Recorded Concentration [mg/kg]	Tier 1 Generic Assessment Criteria [mg/kg]			Samples which exceeded GAC
			Resi w HGP	Resi POS	Commercial	
Arsenic	12.76	75	37	79	640	4 (**Area 1**: WS37 0.7m 41 mg/kg, WS38 0.85-1.1m 58 mg/kg). (**Area 8**: HP3 0.3m 75 mg/kg, HP4 0.0-0.5m 42 mg/kg)
Cadmium	1.47	88	26	220	410	1 (**Area 10**: WS24 0.62-0.80 88 mg/kg)
Copper	245	9,800	2,400	12,000	68,000	2 (**Area 1**: WS38 0.85-1.1m 2,400 mg/kg). (**Area 10**: WS24 0.62-0.80 9,800 mg/kg)
Lead	659	24,000	200	630	2,330	16 (**Area 1**: WS37 0.7m 1,900[1] mg/kg, WS37 1.1-1.4m 210 mg/kg, WS38 0.85-1.1m 10,000[2] mg/kg, WS39 0.41-1.25m 240 mg/kg, WS39 1.25-1.65m 220 mg/kg). (**Area 4:** WS52 1.0m 920[1] mg/kg). (**Area 8:** HP4 0.0-0.5m 300 mg/kg, HP5 0.0-0.6m 360 mg/kg). (**Area 10**: WS24 0.62-0.80 24,000[2] mg/kg, WS26 0.3m 240 mg/kg). (**Area 12:** WS7 0.7m 210 mg/kg). (**Area 15**: WS16 0.4m 810[1] mg/kg, WS16 1.2m 830[1] mg/kg, WS20 0.3-0.5m 510 mg/kg, WS20 1.5m 540 mg/kg, HP1 0.3m 1,100[1] mg/kg).
Zinc	2262	150,000	3,700	81,000	730,000	1 (**Area 10** WS24 0.62-0.80 150,000[1] mg/kg)

1) Exceeds both the residential with home-grown produce and Public Open Space (residential) GACs.
2) Exceeds GACs for all 3 potential land uses.

A total of 24 exceedances for 5 metals were recorded when screening against the most conservative GAC (residential with home-grown produce). Of these exceedances, one concentration of zinc also exceeded the Public Open Space (residential) GAC and 2 concentrations of lead exceeded all 3 GACs. Exceedances were recorded in Areas 1, 4, 8, 10, 12 and 15. Two samples showed significantly elevated concentrations of more than one metal; Area 1: WS38 0.85-1.1m and Area 10: WS24 0.62-0.80.

12.2 Polyaromatic Hydrocarbons (PAH)

PAH are widespread within made ground and the urban environment generally. They are one of the most common contaminants in made ground and the one that most commonly drives remediation. Benzo(a)Pyrene is a particular problem, being very commonly found in association with tarmac, clinker and any burnt products and also being highly toxic to human health. The assessment criterion for BaP is close to levels that are found naturally in topsoil.

The BaP and threshold PAH results have been screened against the GACs for the 3 proposed land uses. Exceedances are summarized in the table below.

There were no exceedances in natural soils.

Table 8: Summary of BaP and threshold PAHs in made ground (70 samples) - mean SOM 2.5%

Determinant	Average Concentration [mg/kg]	Maximum Recorded Concentration [mg/kg]	Tier1 Generic Assessment Criteria [mg/kg]			Samples that exceeded GAC
			Resi w HGP	Resi POS	Commercial	
Naphthalene	0.40	17	5.6	4,900	460	1 (**Area 17**: 0.1-0.3m 17 mg/kg)
Phenanthrene	10.81	290	220	3,100	22,000	1 (**Area 13**: WS1A 0.1m 290 mg/kg)
Benzo(a)pyrene∞	6.88	140	5	10	76	14 (**Area 1**: WS34 0.1-0.2m 10[1] mg/kg, WS35 0.2-0.3m 13[1] mg/kg). (**Area 4**: WS52 0.06-0.28m 53 mg/kg). (**Area 7**: WS41 0.2-0.4m 13[1] mg/kg). (**Area 10**: WS26 0.3m 17[1] mg/kg, WS27A 0.3m 6.3 mg/kg). (**Area 13**: WS1A 0.1m 140[2] mg/kg, WS2 0.3m 57[1] mg/kg, WS3 0.2m 91[2] mg/kg). (**Area 14**: WS4 0.15-0.5m 9 mg/kg). (**Area 15**: WS16 0.4m 9.3 mg/kg, WS18 0.2-0.5m 6.3 mg/kg, WS19 0.4-0.6m 12[1] mg/kg). (**Area 17**: WS28 0.1-0.3m 11[1] mg/kg).

Notes to table

∞ *Used as a surrogate marker for genotoxic PAHs*

1) Exceeds both the residential with home-grown produce and Public Open Space (residential) GACs.

2) Exceeds GACs for all 3 potential land uses.

A total of 16 exceedances for 3 PAHs were recorded when screening against the most conservative GAC (residential with home-grown produce). Of these exceedances, 8 concentrations of BaP also exceeded the Public Open Space (residential) GAC and 2

concentrations of BaP also exceeded the commercial GAC. Exceedances were recorded in Areas 1, 4, 7, 10, 13, 14, 15 and 17.

12.3 Petroleum Hydrocarbons (PHC)

The PHC testing was carried out on 35 targeted samples. No BTEX was detected above the laboratory limit of detection (LOD) in any sample. Furthermore, PHC carbon bands of EC8-10 and below were not detected in any made ground or natural soil sample. The exceedances in made ground are summarized below.

There were no exceedances in natural soil.

Table 9: Summary of petroleum hydrocarbon exceedances in made ground (32 soil samples)

Determinant	Average Concentration [mg/kg]	Maximum Recorded Concentration [mg/kg]	Tier1 Generic Assessment Criteria [mg/kg]			Samples that exceeded GAC
			Resi w HGP	Resi POS	Commercial	
TPH-CWG - Aromatic >EC12 - EC16	26.04	720	330	5,100	37,000	1 (**Area 13**: WS1A 0.1m 720 mg/kg)
TPH-CWG - Aromatic >EC16 - EC21	183	4,800	540	3,800	28,000	1 (**Area 13**: WS1A 0.1m 4,800[1] mg/kg)
TPH-CWG - Aromatic >EC21 - EC35	505	10,000	1,500	3,800	28,000	2 (**Area 1**: WS34 0.1-0.2m 3,700 mg/kg). (**Area 13**: WS1A 0.1m 10,000[1] mg/kg)

Notes to Table

1) Exceeds both the residential with home-grown produce and Public Open Space (residential) GACs.

A total of 4 exceedances for 3 aromatic PHC fractions were recorded when screening against the most conservative GAC (residential with home-grown produce). Of these exceedances, 1 concentration of aromatic EC16-21 and EC21-35 also exceeded the Public Open Space (residential) GAC. Exceedances were recorded in Areas 1 and 13.

12.4 Volatile and Semi Volatile Organic Compounds

No VOCs were detected above the laboratory LOD in any sample. In made ground, the only SVOCs detected comprised the PAHs which have been analysed in Section 12.2. In natural soils the trend was very similar with, (in addition to the PAHs), just a single detection of dibenzofuran (0.9 mg/kg), carbazole (2 mg/kg) and anthraquinone (0.5 mg/kg) above the

laboratory LOD. All detections were in Area 15 (WS18 at 3.2m). Many SVOCs do not have derived GACs. In Leap's experience, these concentrations are not considered significant.

12.5 PCBs and Mineral Oil

PCBs and mineral oil were tested in samples taken adjacent to existing or former electrical substations. No detections were recorded above the laboratory LOD in any instance.

12.6 Flame Retardants

Flame retardants were analysed for in Area 13 (the location of a former fire station). The suite comprised 9 sulphonates and 9 carboxylic acids. One sulphonate (PFOS C8) was detected in all 3 samples at concentrations between 0.4 and 0.7 µg/kg. One carboxylic acid (PFNA C9) was detected in one sample (WS3 at 0.2m) at a concentration of 2.6 µg/kg.

Whilst there are published UK drinking water standards for PFOS and PFOA in the UK there are currently no published human health screening criteria for PFOS or PFOA in soils. The US EPA (Region 4) has published soil screening values of 6mg/kg PFOS and 16mg/kg PFOA for a residential land use and these can be used as a useful indication of potential risk. Based on these criteria the concentrations identified within the soils at the site would not be considered to present a significant risk to human health.

12.7 Asbestos

Seventy soil samples were screened for the presence of asbestos containing materials and/or loose asbestos fibres. Eight positive detections were recorded:

Table 10: Summary of asbestos detections and quantification data

Area	WS ID and Depth [m]	Description	Quantification [% by weight]	Notes
Area 10	WS24 0.08-0.28	Chrysotile- Loose Fibres	<0.001	
	WS24 0.62-0.80	Chrysotile, Amosite- Loose Fibres	<0.001	
Area 15	WS16 0.4	Chrysotile- Loose Fibres	<0.001	
	WS20 0.3-0.5	Chrysotile, Crocidolite- Hard/Cement Type Material	0.001	
	HP1 0.3	Chrysotile- Loose Fibres	<0.001	
Area 16	WS22 0.2-0.4	Chrysotile- Hard/Cement Type Material	<0.001	
Area 17	WS28 0.1-0.3	Chrysotile- Loose Fibres	<0.001	
	WS33 0.2-0.4	Chrysotile- Loose Fibres	<0.001	

Where detections were recorded these are identified primarily as loose fibres of Chrysotile (white) asbestos. Where asbestos was identified as being present it was then quantified. Of the eight samples where asbestos was identified, seven were found to be at concentrations of less than the quantification limit of 0.001%, with one (WS20) being quantified at the detection limit.

13 Analytical Test Results – Water

Two 'grab' samples of perched water were collected from WS24 and WS27A in Area 10. The vast majority of the results returned concentrations below the laboratory LOD (PHC, PAH and VOCs). The full results are provided in the screening table included prior to the laboratory certificates in Appendix E. Section 11.2 and the foot notes provided with the screening table provide more information regarding the adopted screening criteria.

Table 11: Summary of Groundwater Level 2 exceedances (2 samples)

Determinant	Measured Range [µg/l]	Tier 1 Assessment Criteria (µg/l)		Samples that exceed assessment criterion
		UK Drinking Water Standard	Annual Average Environmental Quality Standard	
Cadmium	0.02-1.2	5	0.25	1 (WS24 0.8m)
Chromium	<0.2-11	50	4.7	1 (WS27A 0.7m)
Chromium (hexavalent)	<5.0-6.5	-	3.4	1 (WS27A 0.7m)
Copper	3.1-3.8	2,000	1	2 (WS24 0.8m, WS27A 0.7m)
Lead	0.5-7.4	10	1.2	1 (WS24 0.8m)
Zinc	1.4-2,600	3,000	10.9	1 (WS24 0.8m)

All the exceedances relate to the highly conservative EQS standards. There were no exceedances of the DWS. With the possible exception of the elevated zinc concentration in WS24, the recorded concentrations are not considered to be indicative of significant contamination.

14 Risk Assessment

14.1 Human Health

Fairly limited exceedances have been recorded for metals (arsenic, cadmium, copper, lead and zinc), PAHs (naphthalene, phenanthrene and BaP), heavier fraction aromatic petroleum hydrocarbons and asbestos. The majority of the exceedances relate to the most sensitive residential with home grown produce assessment criteria which would only be applicable to houses with private gardens. Exceedances of the less stringent criteria were largely limited to lead and BaP which are by far the most common contaminants.

The bullet points below summarise what are considered to be the key findings:

- No evidence of fuel contamination in areas where fuel is stored / may once have been stored – Areas 4, 9 and 14;
- Area 1 showed some evidence of heavy metal contamination;
- No evidence of chlorinated solvents in shallow soils in Area 1 (samples taken closest to the known PCE plume area);
- Area 10 showed some evidence of heavy metal and asbestos contamination;
- No contamination found around the below ground strong waste tank in Area 12 (although it was not possible to penetrate through the made ground into the underlying naturals soils below this);
- Area 13 showed some evidence of PAH and TPH contamination;
- Area 15 showed some evidence of lead and asbestos contamination;
- Asbestos detections (with the exception of Area 10) were generally concentrated around the older buildings in the northwest and north of the site (Areas 15-17);
- Locations placed for general site coverage found no significant elevations of any analysed determinants; and
- All of the recorded exceedances related to samples taken in the made ground suggesting that where present, the contamination is shallow and has not migrated into the natural soils.

Given the long industrial history of the site the contamination found during this investigation is considered to be relatively minor. It should however be noted that impacted made ground could be present below buildings (as a result of historical redevelopment). It should be further noted that this investigation comprised windowless and hand excavated locations only (in order to minimise disruption to ongoing site activities). Trial pits may provide a better overall understanding of the nature of the soils particularly with respect to anthropogenic inclusions in made ground (especially asbestos), though this is likely to be highly dependent on location and the specific building history at each location.

The made ground was not found to be particularly deep across the majority of the site and hence it's considered likely that a significant portion would be removed as part of the

construction process in order to install foundations. Based on the findings of this investigation, this would suggest that this would remove the majority (if not all) of the source material. Should impacted made ground not be removed in areas where private gardens or soft landscaping are proposed then cover systems are likely to be required.

Contamination may impact human health through the direct ingestion, inhalation, skin contact and/or plant uptake pathways that would be present in a residential setting. The contamination may pose a risk to incoming water via permeation into supply lines. The use of barrier/protective piling may be required by the water supplier IF made ground were not to be removed.

Once a proposed redevelopment plan is available, further, more detailed site investigation is likely to be required particularly in areas targeted for more sensitive redevelopment (i.e. low density residential). Remediation specifications may need to be prepared depending on the findings but based on the findings of this investigation, remediation requirements (with the exception of the PCE plume) are likely to be relatively straightforward comprising source removal and/or capping.

14.2 Controlled Waters

The site is located above a principle aquifer, the Chalk. The site is situated within an Inner Source Protection Zone (1) and groundwater abstraction boreholes are present on site. Hence, the site is very sensitive from a groundwater standpoint.

No deep boreholes were installed as part of this investigation and no groundwater sampling from standpipes was undertaken. A dataset comprising circa 5 years of sampling data from the existing abstraction boreholes will be analysed with the results reported under separate cover following the issue of this report.

During this investigation 2 samples of perched groundwater were collected from trial holes which could be progressed no further in order to ensure the protection of below ground services. Some minor exceedances of the EQS were recorded and one sample showed an elevated concentration of zinc. There were no exceedances of the DWS and the locations were a significant distance from the nearest surface water feature. Hence, the concentrations of determinants recorded in the 2 samples are not considered to pose a risk to controlled waters.

14.3 Land gases

With no proposed redevelopment plan in place it is not practical to attempt to make any assessment of the risk posed by land gases at this stage.

As made ground was present at thicknesses in excess of 1.0m and the natural soils (alluvium, peat and chalk) present natural sources of carbon dioxide, some assessment of the risk posed by land gases will be required in the future once a redevelopment plan has been produced.

This will likely comprise the installation of gas monitoring wells and the measurement of gases in accordance with the guidance provided in CIRIA 665[9].

The total organic carbon (TOC) content of the made ground and natural soils was generally low (average of 1.4% and a maximum of 4.9%) and there was no evidence of significant organic matter in the vast majority of the recovered soil cores. Furthermore, there was no significant evidence of food products or sewage present in made ground which (potentially) could also degrade to produce land gases.

As discussed with Section 14.1, the removal of made ground would reduce the risk posed by land gases.

14.4 Vapour Risk

Given the absence of any BTEX and other light end hydrocarbon fractions detected, the findings of this investigation suggest that migration of vapours into buildings is not a significant risk at the site. Should hydrocarbon contamination be identified within groundwater and/or within soils during further investigation then this conclusion may require revision and reassessment. A potential exception is the known PCE plume area which will require further assessment in this regard.

15 Waste Disposal

It is anticipated that the proposed development will generate waste soils and materials will need to be removed from site as part of the construction process.

Where soils are to be disposed off-site, it is the duty of the waste producer to ensure that all waste is disposed of appropriately and that any that is sent to landfill is sent to an appropriately licensed one. All waste sent to landfill must be classified and must be pre-treated. The form of pre-treatment should be documented in the Site Waste Management Plan. There are various forms of pre-treatment that are acceptable. In this case it could include "reduction in volume", which could be achieved by segregating the Made Ground and re-using part of it on site.

Where made ground soil is to be re-used on site then it is recommended that this is carried out under the CL:AIRE Definition of Waste Industry Code of Practice (DoW CoP) for re-use of soils[10]. The testing of soils destined for offsite disposal will be required in order to classify

[9] CIRIA 665 Assessing risks posed by hazardous ground gases to buildings 2007

[10] The Definition of Waste: Development Industry Code of Practice. Version 2 2011. CL:AIRE

the waste. Such testing should be undertaken well in advance of the required disposal date with appropriately licensed waste facilities and hauliers also identified and engaged in advance of the required disposal date.

16 Recommendations

Site Wide

Access into some areas of the site was restricted due to buildings, roads and services. It is recommended that once the factory is closed (or ideally once structures have been demolished and hard standing removed), formation inspections and further intrusive investigations (trial pits) are undertaken. Following the additional investigations, remediation strategies to mitigate risks to the proposed development from identified contamination may need to be prepared.

Land gas risk assessment is likely to be required once redevelopment proposals are available.

An assessment of the groundwater quality at the site is required. This should commence with a detailed review of all available data. Following this assessment, further groundwater monitoring standpipes and sampling may be required to delineate any contamination and/or fill any identified data gaps.

Area 12: pH Balancing Plant and below Ground Strong Waste Tank

Further investigation should encompass deeper excavation in the vicinity of the below ground strong waste tank as WS locations could only penetrate to a maximum depth of 3.5m when the base of the tank may be as deep as 4.65m. Investigation around the acid and alkali tank bund in the pH balancing area should also be undertaken as there was evidence of damage to the concrete bund as a result of exposure to acid / alkali.

PCE Plume Area

The known PCE plume in the north east of the site requires further assessment. This work is planned to be undertaken following the issue of this document and reported under separate cover. This work is envisaged to comprise:

1) Critical data review. A significant amount of work has already been carried out by others which requires critical review in order to assess any data gaps and determine the suitability of the existing model for the purposes of assessing the impact of the proposed closure of the site and various remediation proposals.
2) Near surface shallow soils investigation. Additional intrusive work to assess the near surface soils and shallow groundwater in the area of the PCE spill to determine whether any primary source material is still present (and whether there is a potential vapour intrusion risk). This should include detailed soil logging to determine lower permeability horizons and selective sampling to target these layers.

3) Groundwater modelling and DQRA. A groundwater model needs to be constructed to demonstrate the likely effects on the PCE contamination of a) turning off the existing abstractions at the site and b) the impact of any new abstraction constructed for remediation purposes. This DQRA will be critical to demonstrate the suitability of any proposals to the Environment Agency. This is anticipated to build on and update the work carried out by others which has been previously accepted by the Environment Agency.

4) Options Appraisal. A detailed remediation options appraisal will need to be produced based on the outcome of the DQRA/groundwater modelling setting out potential remedial options, estimated costs and likely timescales. This options appraisal will then need to be submitted to the Environment Agency for their approval of the preferred option.

5) Remediation Pilot Trials. It may be necessary as part of the Options Appraisal to carry out some remediation pilot trials in order to demonstrate the likely effectiveness of remediation proposals.

6) Remediation Method Statement. Once an agreed Remediation methodology has been decided upon then a remediation method statement (RMS) will be prepared.

7) Remediation and Validation. Once the remediation contractor has been selected then the effectiveness of the remediation work carried out will need to be independently validated to provide assurance to the regulator as to its effectiveness.

17 Conclusions

Fairly limited exceedances have been recorded for metals (arsenic, cadmium, copper, lead and zinc), PAHs (naphthalene, phenanthrene and BaP), heavier fraction aromatic petroleum hydrocarbons and asbestos in made ground. No exceedances of any determinants were recorded in any natural soil sample.

As there are currently no redevelopment plans available it is not possible to make an assessment of any remedial actions which may be required at this stage. However, should impacted made ground soils not be removed as part of the construction / redevelopment process then clean cover systems would likely be required in private gardens and areas of soft landscaping.

An assessment of the risk posed by land gas will need to be undertaken once development proposals have been produced. The results of this study indicate that the risk of vapour intrusion into buildings (outside of the known PCE plume area) is low.

An assessment of the groundwater quality at the site will need to be undertaken. This should commence with a detailed review of existing data.

Some further intrusive investigation will inevitably be required once redevelopment proposals are available and the factory has closed (which will relieve some of the constraints of investigating the site).

Further work will be required with respect to the known PCE plume in the north east of the site. This work is necessary to understand the effects of switching off the current abstractions at the site. A series of proposed steps to achieve this is provided in the recommendations section.

APPENDIX A – LIMITATIONS

Limitations

LIMITATIONS

This report is confidential to the Client and Leap Environmental Ltd accepts no responsibility whatsoever to third parties to whom this report, or any part thereof, is made known, unless formally agreed by Leap Environmental Ltd beforehand. Any such party relies upon the report at their own risk. Unless explicitly agreed otherwise in writing, this report has been prepared under LEAP's standard terms and conditions, as included in the quotation for this works.

This report has been prepared by Leap Environmental Ltd on the basis of information received from a variety of sources which Leap Environmental Ltd believes to be accurate. Nevertheless, Leap Environmental Ltd cannot and does not guarantee the authenticity or reliability of the information it has obtained from others.

Leap Environmental Ltd has used all reasonable skill, care and diligence in the design and execution of this report, taking into account the manpower and resources devoted to it in agreement with the Client. Although every reasonable effort has been made to obtain all relevant information, all potential contamination, environmental constraints or liabilities associated with the site may not necessarily have been revealed. LEAP cannot be held responsible for any disclosures or changes in regulation that are provided post production of this report and will not automatically update the report.

The conclusions reached in this report are necessarily restricted to those which can be determined from the information consulted and may be subject to amendment in the light of additional information becoming available. These conclusions may not be appropriate for alternative schemes.

The extent of the exploratory holes, laboratory testing and monitoring undertaken may have been restricted due to a number of factors including accessibility, the presence of buried or overhead services, current development and site usage, timescales or client's specification. The exploratory holes only assess a small proportion of the site area with respect to the site as a whole, and as such may only provide an overall assessment of ground conditions on site. The presence of hotspots of undisclosed contamination or exceptional and unforeseen ground conditions cannot be discounted.

The presence of asbestos may be noted during the site walkover survey, intrusive investigations and/or from the results of contamination testing. However, this report does not constitute an asbestos survey. On this basis, the presence of asbestos on site cannot be discounted and a full asbestos survey should be undertaken.

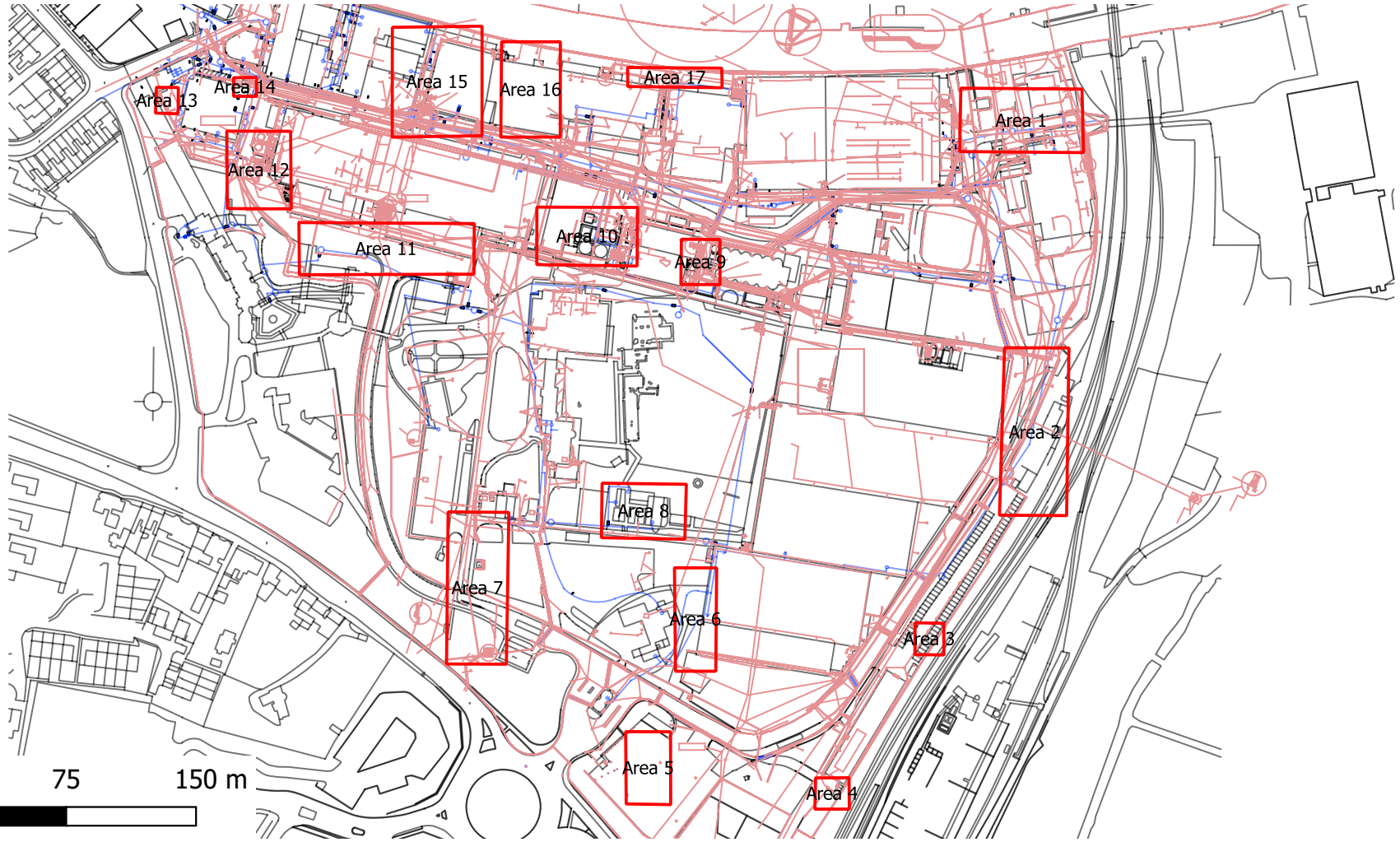
APPENDIX B – FIGURES

Figures

0 100 200 m

leap environmental

Client:	Uniliever (UK) & Britvic	Title:	Site Location Plan	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	06/07/2018	Figure No.	1

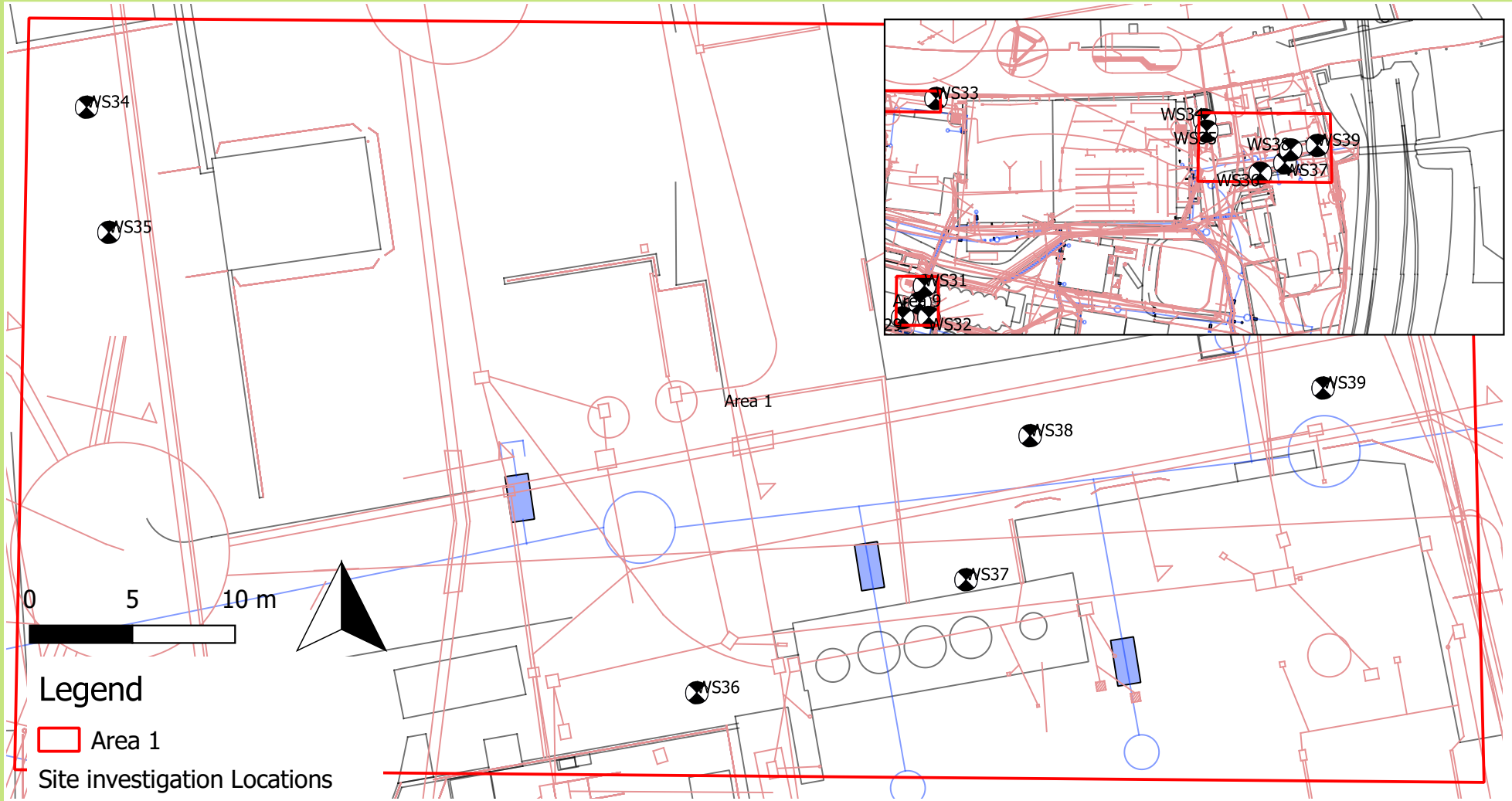


Legend

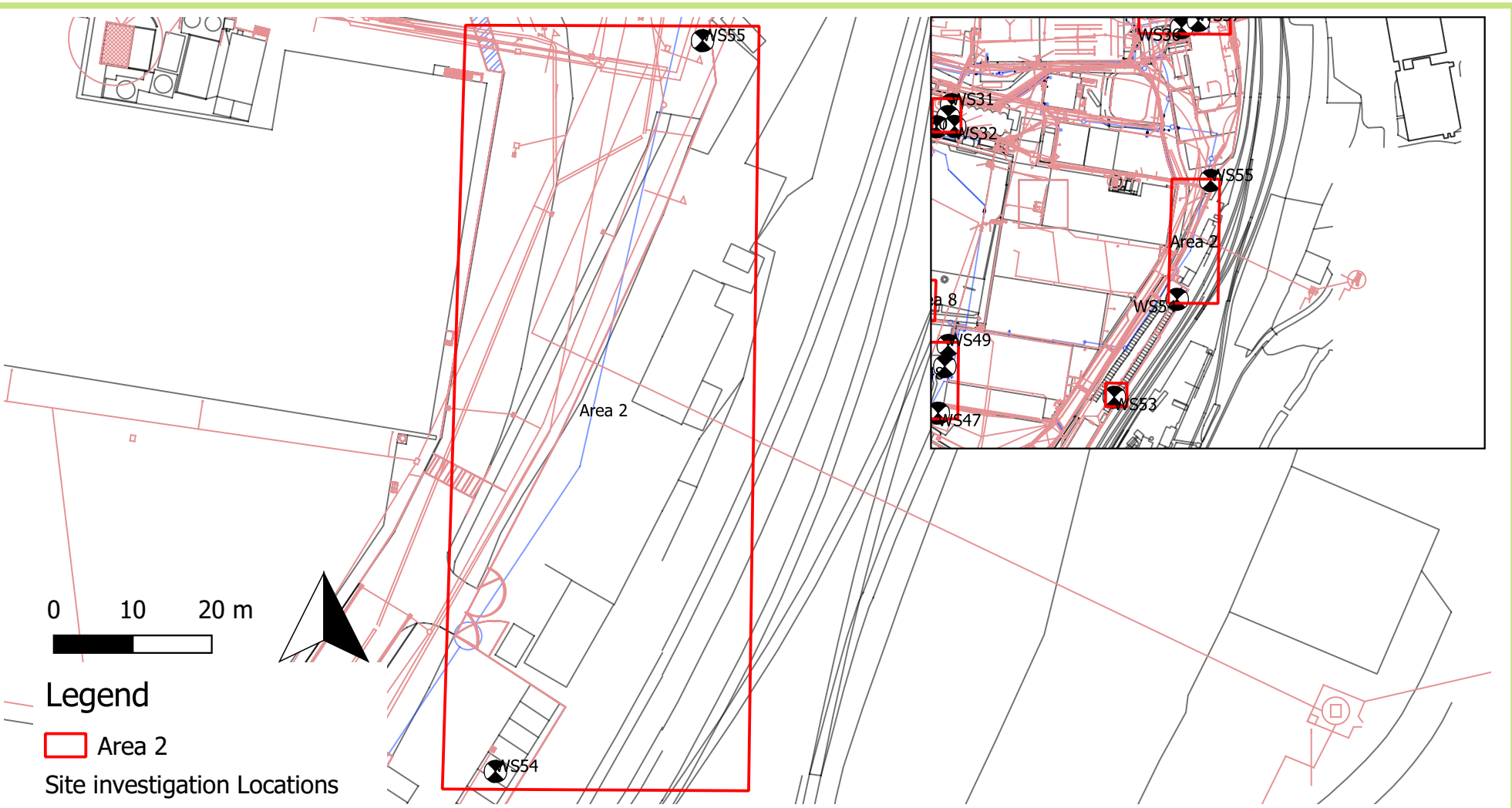
- Map Sections
- Site Layout

leap environmental

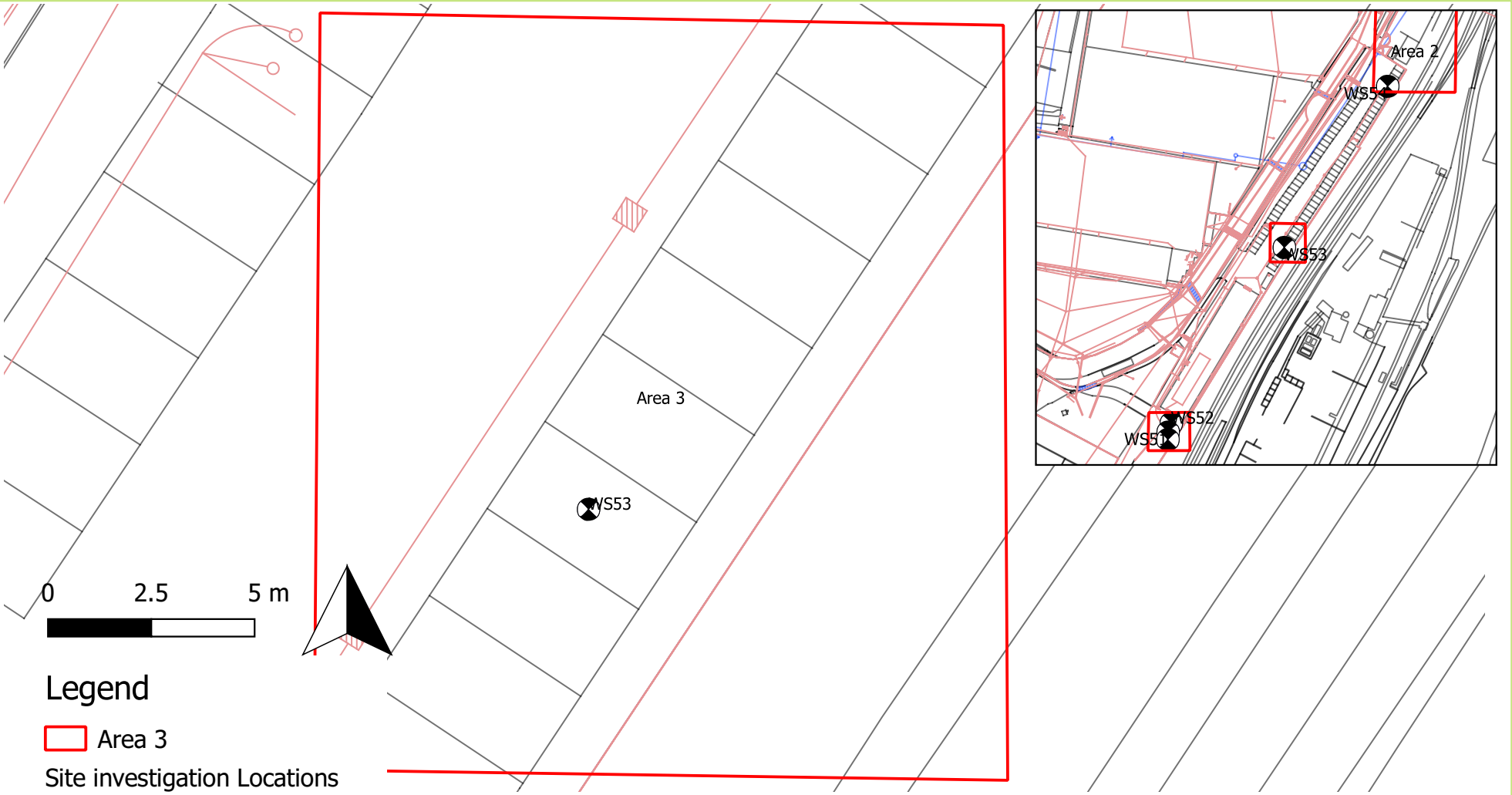
Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area Location Plan	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	2



Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 1	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	3



Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 2	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	4



Legend

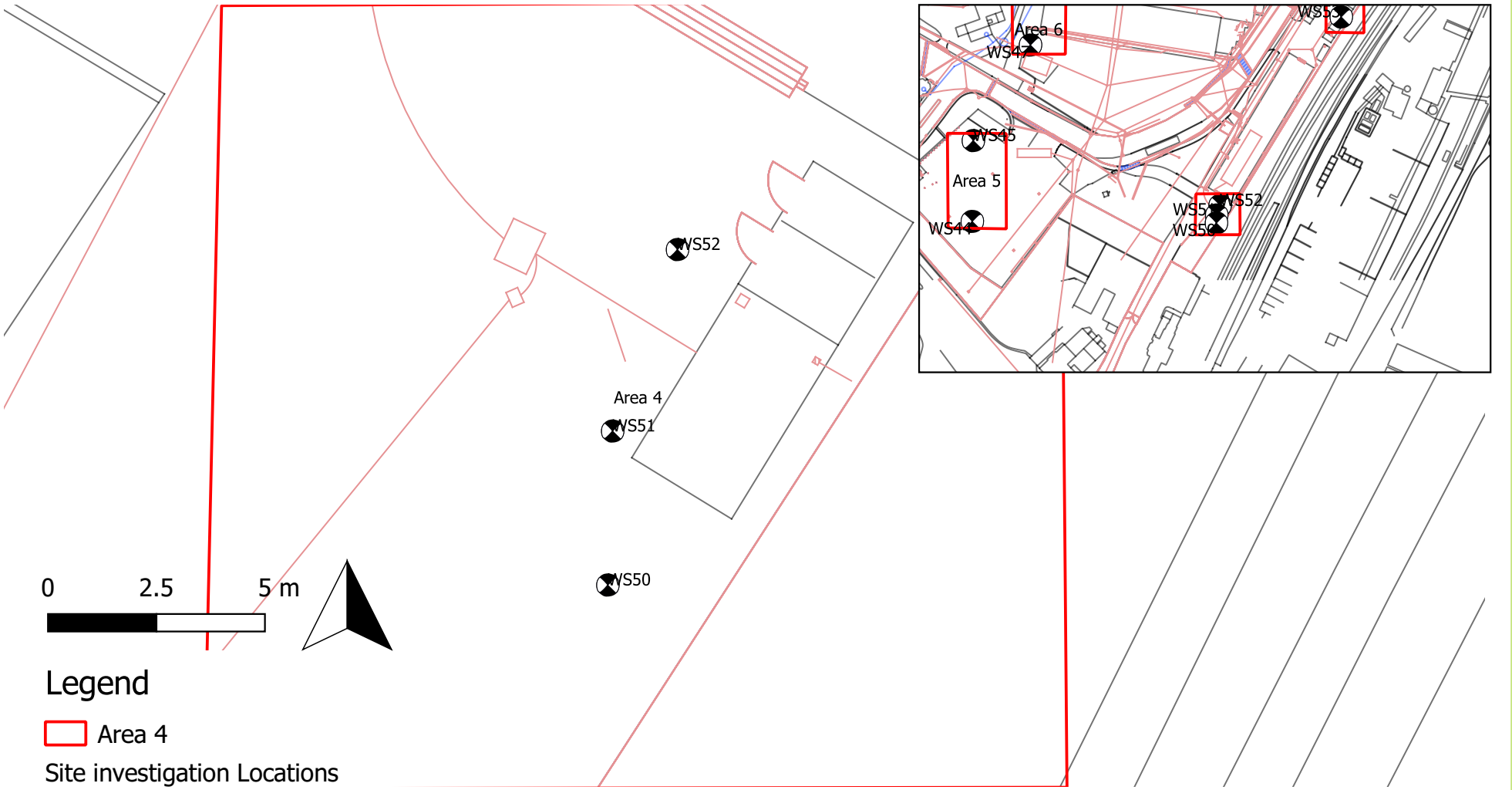
- Area 3

Site investigation Locations

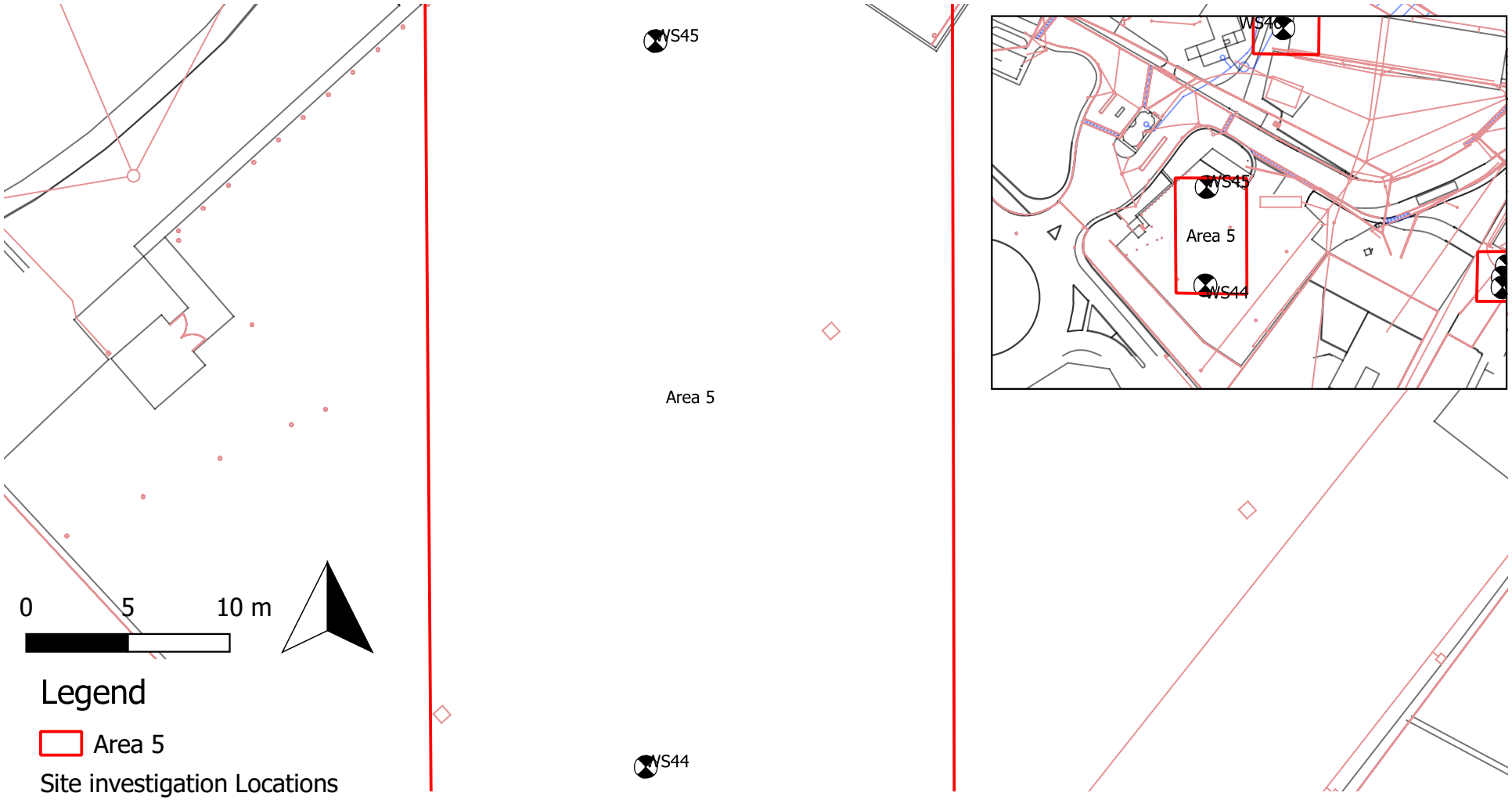
- HP
- WS
- Service Plan 1 (Sitem12a)
- Service Plan 2 (Sitem16a)

leap environmental

Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 3	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	5



Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 4	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	6



Legend

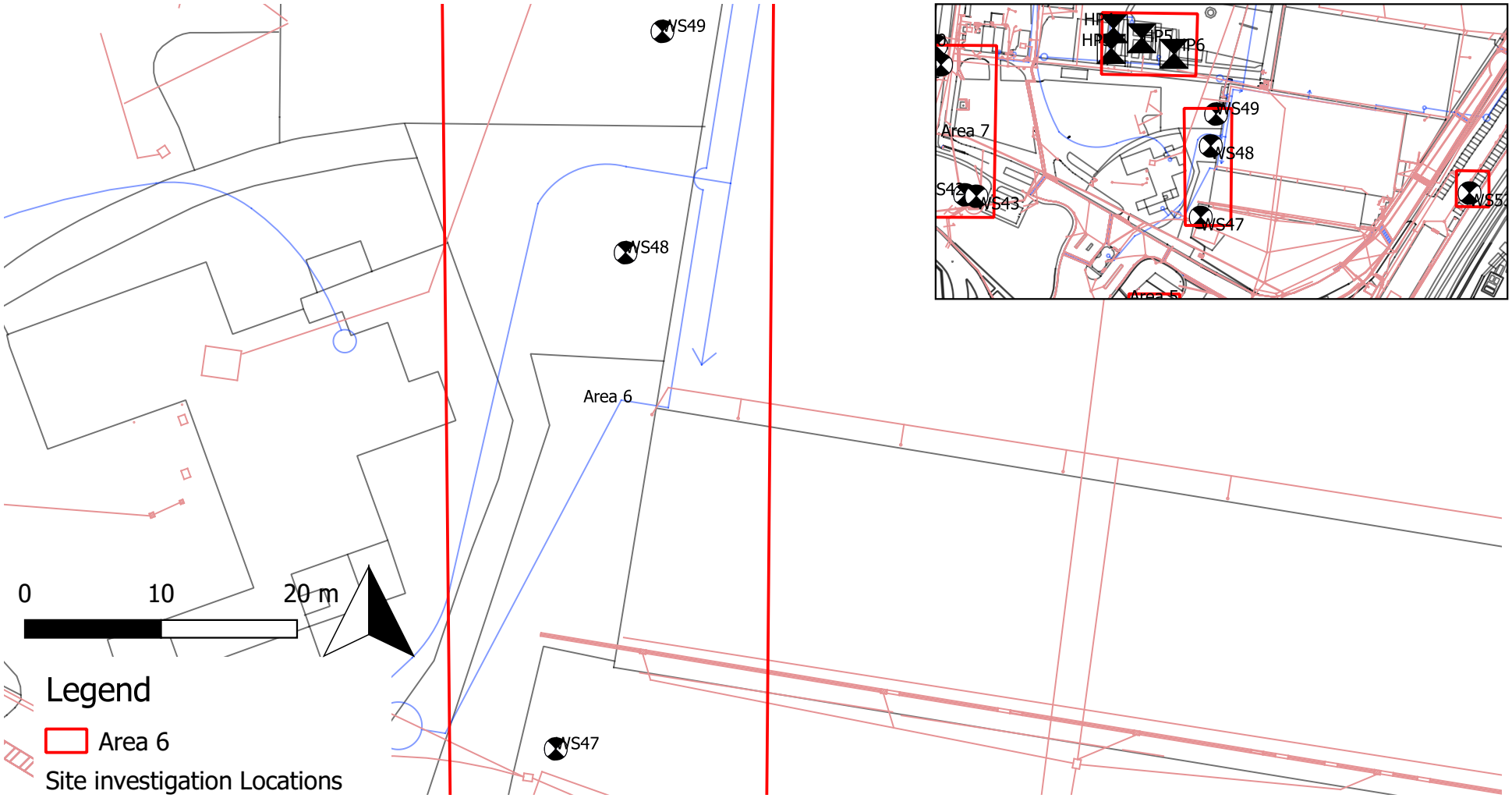
- Area 5

Site investigation Locations

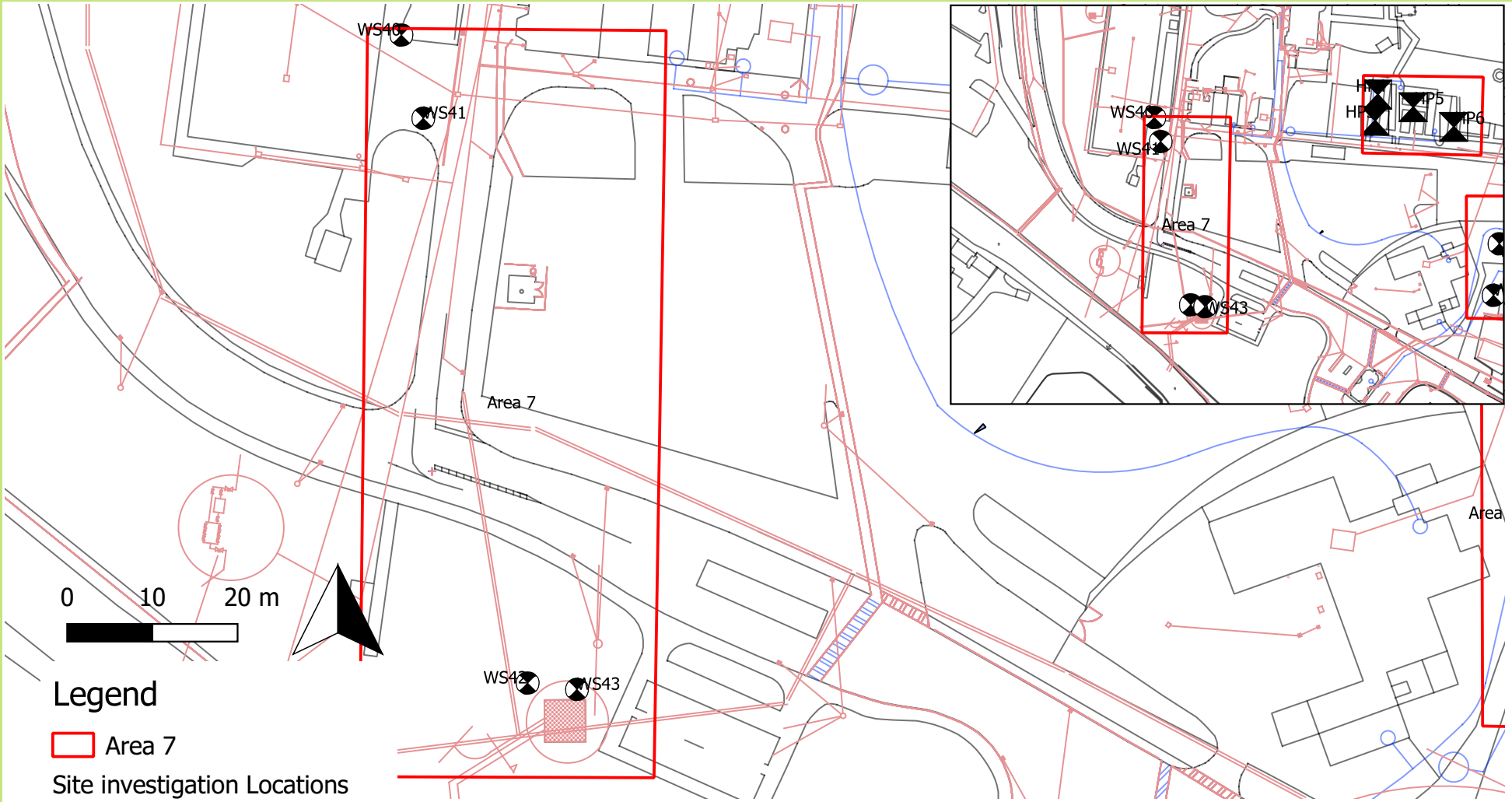
- HP
- WS
- Service Plan 1 (Sitem12a)
- Service Plan 2 (Sitem16a)

leap environmental

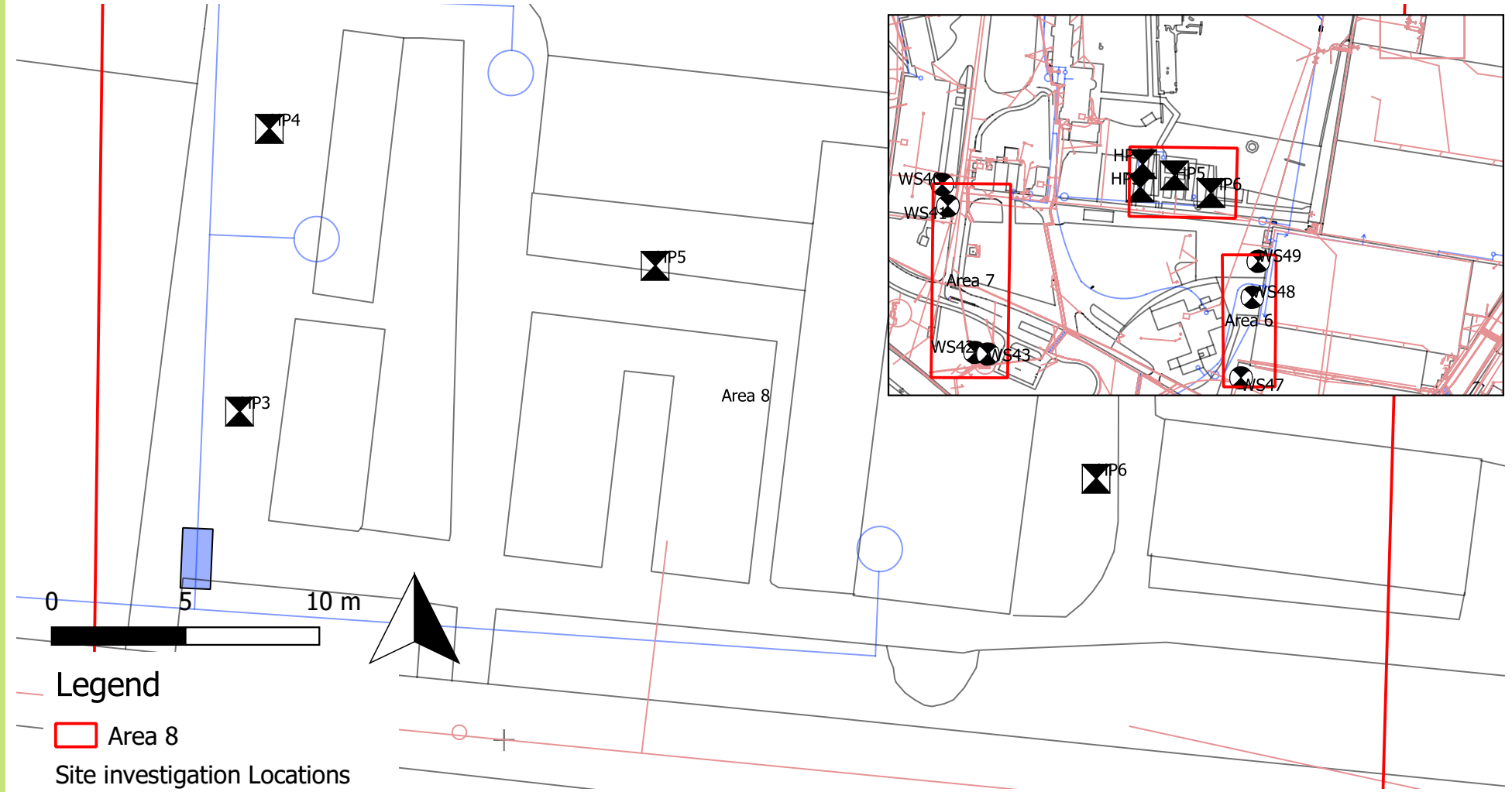
Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 5	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	7



Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 6	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	8



Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 7	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	9



Legend

- Area 8

Site investigation Locations

- HP
- WS
- Service Plan 1 (Sitem12a)
- Service Plan 2 (Sitem16a)

Client:	Britvic soft Drinks & Unilever (UK) Ltd.	Title:	Area 8	Project ID:	LP01671
Project:	Carrow Works, Norwich	Date:	03/08/2018	Figure No.	10