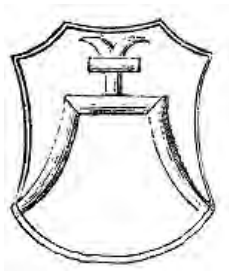

Phase 3 Geo-Environmental Investigation

Nos. 389-389A Gosbrook Road & Nos. 2-4 Send Road,
Caversham
Reading
Berkshire
RG4 8EH

Project Reference J163A



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NOTES TO THE REPORT

This report has been prepared by Julian Puzyna for and on behalf of Sackedgate Ltd. Company registered No. 09712671 at 26 Reading Road, Burghfield Common, Berkshire, RG7 3QA. (director and sole employee of Sackedgate Ltd). This report was produced for the benefit of the client detailed in the appointment section of the report and subject to the provisions set out in the document below and also within the Sackedgate Ltd estimate and terms of engagement prepared for this project.

Investigator and Author of this Report

The investigations, either desk based or physical examinations of this site were carried out and documented by myself, Julian Puzyna. I have an Honours degree in Civil Engineering (BEng Hons) from Kingston University (Kingston Upon Thames) and I am a member of the Chartered Institute of Environmental Health (MCIEH).

My first contaminated land investigation as lead engineer was carried out in 1998 however my first involvement with contaminated land investigations was in 1989 with Exploration Associates Ltd. at the Bell Green Gas Works in East London. Since then, I have carried out approximately 858 ground investigations (as of March 2023).

I am currently project leading a new British Standard/Code Of Practice for the use of XRF analysers in contamination investigations complementary to the Environment Agency Land Contamination Risk Management (LCRM) system. I am also on the panel for review and revision of BS 10175 Code of Practice for the Investigation of Contaminated Sites and have already provided guidance for the use of XRF analysers in the updated BS10175 standard.

Applicable Guidance

The investigations and methods used were carried out with reference to the Environment Agency Land Contamination Risk Management (LCRM) system which itself lists many other guidance and standards such as BS EN ISO 21365:2020 (Conceptual site models for potentially contaminated sites), BS 10175 (Code of Practice for the Investigation of Potentially Contaminated Sites) and BS 5930:2015 (Code of practice for ground investigations).

Other applicable guidances have also been referred to wherever appropriate, such as the Environment Agency Framework for the Use of Rapid Measurement Techniques (RMT) in the Risk Management of Land Contamination (March 2008), BS EN ISO 13196- Soil Quality — Screening Soils For Selected Elements By Energy-Dispersive X-Ray Fluorescence Spectrometry Using A Handheld Or Portable Instrument (2015).

Confidentiality

This report is produced in confidence. The report, the associated documents and the investigation records will not be divulged to any other parties without the express permission or instruction from the client detailed in the report text. This applies to any drawings, proposals, previous investigations or correspondence supplied by the client which is applicable for the site under investigation. Client details are held for communication, document transfer and billing purposes only. This information is not shared with any other parties whatsoever. A full copy of the client's details kept by Sackedgate Ltd is available on request.

Reliance

This report was commissioned by the client detailed in the appointment section of the report introduction. This client has reliance on the report, as set out in the terms and conditions of the estimate for completion of the report. This reliance is not transferrable and cannot be sold/given/passed on to any third parties without that third party first forming a specific agreement/contract with Sackedgate Ltd.

Limitations

This assessment has been carried out with reasonable skill, diligence and care with reference to applicable guidance and accepted practice. The agreed scope of investigations with limitations on unexpected or exceptional circumstances, limits to liability and professional indemnity insurance, are set out in the estimate and the terms of engagement. It is not always possible to predict the exact nature of the historical use of any site or the full geological or hydrological setting from the available records. Ground conditions may vary between investigation locations and whilst likely or predictable variations will be taken into account, unusual issues may not be predicted or subsequently disclosed by physical investigations. It should therefore be understood that a level of uncertainty will always remain after any investigation, no matter how extensive the scope of that investigation or the diligence with which it was carried out.

Discussions are made in this report about geology and ground conditions solely with respect to an environmental assessment. This report should not be used or relied upon in any way for the assessment of liabilities from, or for the design of, foundations, slopes, substructures or drainage etc. or for the assessment of ground stability, shrinkable clays, swallow holes, dissolution features or mine workings etc. This should be carried out by a geotechnical specialist.

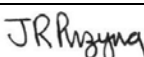
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Table of Contents

1.0	Introduction	5
1.1	Appointment	5
1.2	Proposed Development	5
1.3	Scope of Investigation	5
2.0	Site Details	5
2.1	Site Location.....	5
2.2	Published Geology.....	5
2.3	Site History	6
2.4	Site Description	6
2.5	Encountered Stratigraphy	7
2.6	Contamination Analysis	7
2.7	Phase 2 Report Recommendations.....	7
3.0	Physical Investigations	8
3.1	No. 389 Gosbrook Road Workshop & 389A Gosbrook Road Bungalow (Paint Shop) .	8
3.2	No. 2 Send Road (Bungalow).....	9
3.3	No. 4 Send Road (Tyre Shop)	10
3.4	Post Demolition.....	11
3.5	Uninspected Areas	11
3.6	Groundwater	12
3.7	Soil Sampling and Analysis	12
4.0	Contamination Analysis	12
4.1	Samples of Soil (& Soil Like Material)	12
4.2	Scheduled Analysis	13
4.3	Assessment Methodology.....	13
4.4	Comparison of Measurements with Guideline Values	14
4.5	Summary of Assessment.....	17
5.0	Conceptual Model.....	17
5.1	Made Ground On-Site	18
5.2	Stables & Kitchen Gardens to Ivy Cottage Farmhouse	19
5.3	Workshop, Garage & Paint Shop (389 Gosbrook Rd)	20
5.4	Workshop, Tyre Fitters & Printers (No.4 Send Road)	21
5.5	Forge	22
6.0	Conclusions on the Source-Pathway-Receptor Model	23
7.0	Recommendations	23
7.1	Further Investigations	23
7.2	Remedial Works	24
7.3	Surplus Soil.....	24
7.4	Soil Disposal to Landfill	25
7.5	Imported Soils	26
7.6	Validation	26
8.0	Xray Fluorescence Validation.....	27
8.1	How It Works.....	27
8.2	Note on the Ionising Radiation Regulations (IRR2017).....	28
8.3	Implemented Safety Measures.....	28
8.4	Homogeneity.....	28
8.5	Limitations.....	28
8.6	Testing Blank	29
8.7	Moisture Content.....	29



8.8	Qualitative or Quantitative	29
8.9	Validation Laboratory Analysis	29
8.10	Laboratory VS XRF Analyser Comparisons	30
8.11	Comparison for Lead	31
8.12	Laboratory vs Analyser (Other Elements)	31

Figure Pages

1	Site Location
2	Site Layout
3	Proposed Layout (Nos.389-389A Gosbrook Road)
4	Proposed Layout (Nos.2-4 Send Road, Caversham)

Appendices

A.	Site Photographs
B.	Laboratory Results (Phase 2 & Phase 3)
C.	XRF Analyser Results
D.	Soil & Water Contamination Assessment Criteria

1.0 Introduction

1.1 Appointment

This report was commissioned by Darcliffe Homes Ltd. to provide an environmental assessment of the soils underlying the proposed development site at Nos. 389-389A Gosbrook Road and Nos. 2-4 Send Road, Caversham following demolition and clearance of the site.

The work was carried out on the basis of Sackedgate Ltd estimate No E189A and subject to the provisions set out in the estimate and the terms of engagement included with that estimate.

1.2 Proposed Development

This site comprises three separate properties with associated buildings. One was in residential use and two were in commercial use. Following the recent removal of these existing buildings, the construction of a number of new residential dwellings is proposed. Proposed layouts are presented in the figures section at the end of this report.

1.3 Scope of Investigation

This report follows on from the Sackedgate Ltd. phase 2 investigation report referenced J163 and dated January 2023 (revised August 2023 to include clarification on landfill gases). The preceding Sackedgate Ltd phase 2 report reviewed desk study investigations of this site by Stantec and Syntegra and included physical investigation of the ground below site by boreholes and shallow hand excavated pits where access allowed.

Setting out the preliminary contaminant findings in the conceptual model showed that risks have been identified to future residents by the thin dark ashy topsoil layer present at every exploratory hole location. The investigations also showed that there were no plausible source of gases in the surrounding area, nor were there any identifiable gas migration pathways below the site.

The Sackedgate Ltd. phase 2 investigation report recommended that further investigations will be required once the buildings have been removed and the site is cleared. The footprints of the buildings as well as the wider site should be examined in detail and additional machine excavated trial pits carried out in any suspicious areas.

2.0 Site Details

2.1 Site Location

This site lies in Lower Caversham one of Reading's older residential areas about 1.64km north east of central Reading (Civic Centre). The site is on the northern side of the River Thames which flows just 220m to the south of the site.

The centre of the proposed development site lies at grid reference SU 72394 74501. The postcode for the site is RG4 8EH.

2.2 Published Geology

Data from the British Geological Survey shows that the site is underlain by the Langley Silt Formation, formerly known as Brickearth Clay overlying the Kempton Park Gravel (River Terrace Deposit). Underlying the gravels the maps show the Seaford Chalk and Newhaven Chalk Formations to be present, the maps do not differentiate between the two formations.

2.3 Site History

Historical mapping showed that the site area was formerly the kitchen garden and stables to neighbouring Ivy Cottage Farmhouse, a 17th century Grade II listed building that was originally an isolated farm house.

The older long section of the workshop at 389 Gosbrook Road appeared to be a stable for the Farmhouse. The stable was turned into a commercial property of its own and the footprint we see today is first shown on the 1956 map. The building appears to have been a vehicle maintenance and/or respray workshop up until the present day.

The bungalow at No. 2 Send Road and workshop at No.4 Send Road also appear on maps dated 1932 and 1936. The workshop at No.4 Send Road also appears to have been for vehicle maintenance and/or respray workshop, then a lithographic printer and then a tyre fitters.

2.4 Site Description

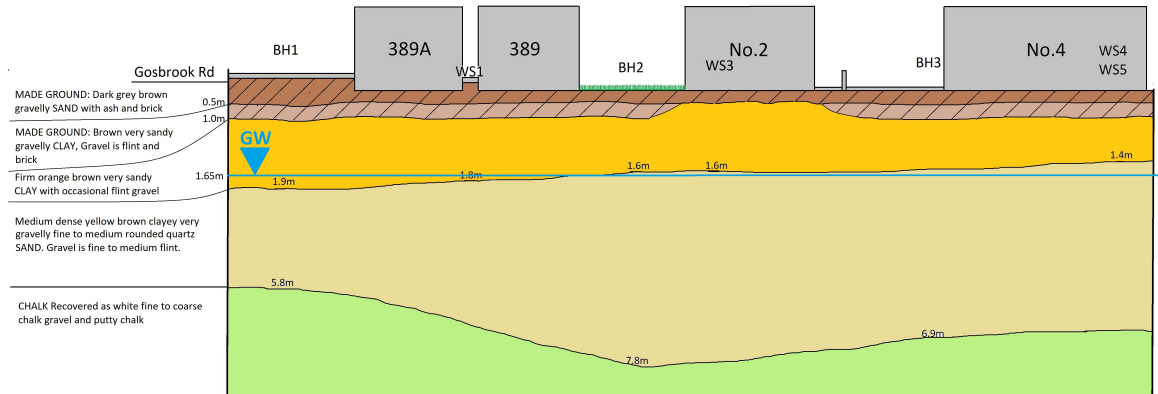


Above, a view looking south along Send Road to the right of the picture.

At the time of writing this report, the site had been cleared with bare soil visible at the surface at all locations. A full description of the site and the buildings present is given in the preceding Sackedgate Ltd. phase 2 investigation report which is available on request.

The only remaining structure on the site was the wall to an old workshop building, which was suspected to be a very old former stable block to neighbouring Ivy Cottage Farmhouse (No.393 Gosbrook Road. The wall is painted white and visible on the left of the picture above. This wall acts as the boundary between the site and Ivy Cottage and is faced with knapped flint as seen on Ivy Cottage. This wall is understood to be part of the listed structures associated with Ivy Cottage and was successfully preserved.

2.5 Encountered Stratigraphy



Above, a sketch section of the geology below the site (not to scale)

The phase 2 investigations revealed a surface layer of dark grey brown ashy topsoil with brick fragments. This was suspected to be the original topsoil layer from around Ivy Cottage Farmhouse. The remnant topsoil layer was seen to be overlying a thin layer of made ground variably comprising brown sandy gravelly clay, also with brick fragments.

Below the topsoil and made ground the geology was largely as expected, Langley Silt (recovered as orange brown variably sandy gravelly clay) was seen over the river terrace deposit called the Kempton Park Gravel (recovered as gravelly sand). Below the sand and gravel we saw the Seaford and Newhaven Chalk Formations (recovered as chalk gravel, chalk fines and flint).

2.6 Contamination Analysis

The preceding phase 2 investigations showed sporadic but excessive concentrations of lead as well as the PAH compounds Benzo (b) fluoranthene and Dibenzo (a,h) anthracene in samples from the topsoil and in some places the made ground layer including the residential garden of No. 2 Send Road. Contamination was not found in the samples of the underlying natural clays or river terrace gravels.

Screening for asbestos fibres was carried out on all samples and no fibres were detected in any of the samples. Fragments of corrugated cement boards or other asbestos containing materials were not observed in any of the borehole or hand pit arisings

2.7 Phase 2 Report Recommendations

“Further investigations will be required once the buildings have been removed and the site is cleared. The footprints of the buildings as well as the wider site should be examined in detail and additional machine excavated trial pits carried out in any suspicious areas”.

“The most important area for further investigations at this stage is expected to be the rear yard to the tyre fitters at No. 4 Send Road where tyres and other waste has prevented a full inspection of the yard. Of particular concern in this area is the suspected aqua-cell type soakaway to the rear of the yard, as well as the ground at the front of the tyre fitter workshop where there is anecdotal evidence for the presence of buried asbestos waste”.

“The dark ashy soil layer is relatively thin and possibly absent below buildings. This material should not be left in place or reused in garden areas. Considering the absorption pathways for the contaminants present in this layer, it can be seen that the layer could remain in place where sandwiched between the underlying clay below and a building or non-permeable hardstanding above, with the exception of garden patio areas”.

3.0 Physical Investigations

Sackedgate Ltd attended the site on the 12th February 2024 and witnessed the lifting of the floor slabs for No.4 Send Road. Then on the 21st February Sackedgate Ltd witnessed the lifting of the floor of the paint shop at No.389A Gosbrook Road. A final visit was then made on the 23rd February 2024 to examine the fully cleared site. Details of each area are presented below. More photographs are appended and all 328 photographs taken on the site remain on file with Sackedgate Ltd and are available on request.

3.1 No. 389 Gosbrook Road Workshop & 389A Gosbrook Road Bungalow (Paint Shop)



The breaking up and removal of the hardstanding from below these buildings revealed differing areas of concrete slabs, varying in thickness and apparent age. The foundations of the buildings were very shallow and the floor slabs appeared to have been poured directly onto the dark grey brown ashy topsoil layer. Below the ashy topsoil was the paler coloured made ground comprising largely Langley Silt with intermixed possibly trafficked brick fragments.

A patch of blackened soil was noted below the footprint of the old stable block (see pic page 11). There was no notable smell of solvents or fuel however, a sample of this material referenced Paint Shop 2 was recovered and scheduled for additional detailed semi volatiles (SVOC) analysis. Some further excavation showed this was not a plume of contamination it was just a smear of blackened clay.

The inspections did not reveal any evidence for any asbestos containing materials. The asbestos cement boarded roof of the building was seen previously to have been carefully dismantled and the material placed in a designated covered skip for removal.

The remnant foundations of the building were shallow as discussed and included what appeared to be an old drain chamber. This chamber was found to be filled with fragments of asbestos cement roof board (see pic page 11). This was cleared by the demolition contractor by hand and bagged to go into a dedicated asbestos skip. Once the remaining rubble had been removed, a final inspection of the exposed ground was carried out and two samples were recovered.

3.2 No. 2 Send Road (Bungalow)



Above, a view of the boundary wall between Ivy Cottage and No.2 Send Road.

Although the bungalow was inspected before demolition, the demolition process was not witnessed by Sackedgate Ltd.



No sources of contamination had been found on that property such as fuel oil tanks or garage workshops where careless disposal of used oil had taken place and there was no evidence for scattered oil filters or brake pads anywhere on the property. The building was clearly connected to the mains gas supply.

Above, disconnected gas meters inside No.2 Send Road

The exposed ground was however, closely inspected following removal of the scrap metal liberated from the demolition of the bungalow which is visible in the picture above.

Brick and concrete fragments were present in the dark grey brown surface topsoils where the bungalow structure previously stood. The garden area, now stripped of turf, was covered by a dark grey brown topsoil with far fewer brick inclusions and consistent with the soils encountered by borehole WS3 during the phase 2 investigations.

There was no evidence seen for any asbestos containing materials. The dark grey brown topsoil was also present below the bungalow and in its garden area.

In the absence of any visible plumes or patches of visible or odorous contamination or evidence of asbestos containing materials, further excavations were not requested by Sackedgate Ltd and a single sample was recovered from the former footprint of the bungalow for laboratory analysis.

3.3 No. 4 Send Road (Tyre Shop)



Above, the ground below the Tyre Shop

The concrete slab covering part of the yard area and below the actual tyre shop itself was seen to be very thin, just 0.1m in most places and cast directly onto the dark grey brown topsoil.

There was no granular layer below the concrete, just a thin woven membrane of some kind. The underside of the slab was inspected carefully to ensure that there were no signs of any asbestos cement fragments adhered to the base of the slab, none were observed.

The process of removing the foundations showed that where present, they had been placed at very shallow depth (estimated 0.5m) into the made ground layer below the topsoil. The made ground layer was difficult to differentiate from the sandy gravelly clay of the Langley Silt Formation. This was because the made ground appeared to be derived from the underlying Langley Silt. Further excavation into these materials was avoided to prevent damage to the underlying strata with respect to new foundations.

No visible plumes of fuel, oil or solvents were found below the slab. There was no sudden release of volatiles on removing the slab. The only perceivable odours were that of long decayed vegetative matter in the topsoil. There was no evidence seen for any asbestos containing materials.

Drainage channels were present in the yard behind the tyre shop. It was assumed that these would be connected to the soakaway anecdotally suggested to be present in that yard to provide road drainage for the end of Forge Close to the east. Excavation in the expected location of the soakaway, and also following a drain pipe from a grate in the yard, did not reveal a soakaway of any kind, just the undisturbed top of the Langley Silt Formation.

3.4 Post Demolition

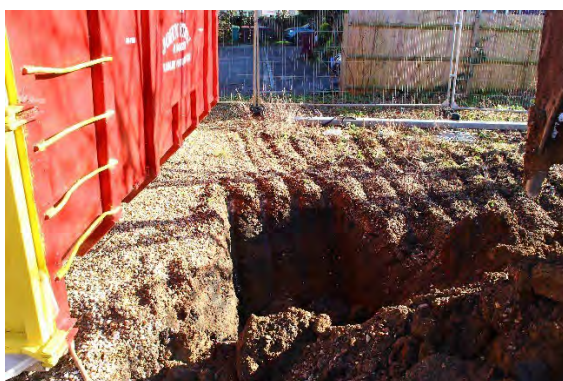


Above, a view of the cleared site with Send Road visible in the background.

Once all of the hardstanding, foundations and drainage had been removed a final inspection was carried out over the whole site area on the 23rd February 2024. The ground surface was being smoothed over by the demolition contractor and the inspection was carried out to see if any asbestos containing materials had been revealed following the final removal of rubble and other demolition waste. There was no evidence seen for any asbestos containing materials or any other forms of visually identifiable contamination.

3.5 Uninspected Areas

Two small areas remain uninspected, the first is adjacent to Send Road, in the area of the forecourt to the tyre shop where shipping containers are present (see picture above in section 3.4). There was some anecdotal evidence for the presence of buried asbestos cement roof board in that area.



The second area is a small section of ground adjacent to Forge Close which was used by the demolition contractors as an access point. The asbestos skip and subsequently a trailer for equipment prevented full examination of that area. Again, there was anecdotal evidence for the presence of an aqua cell soakaway for Forge Close somewhere at the boundary between the site and Forge Close. No evidence was found for such a soakaway however, this small area has not been explored.

3.6 Groundwater

Monitoring well pipes were installed into the three deep cable percussive boreholes on the site during the phase 2 investigations. Monitoring was carried out shortly after installation and then during the recent site visits as set out below.

Borehole	6,7 Dec 2022 (immediately after drilling)	5-14 Dec 2024	25 Jan 2024	12 Feb 2024	23 Feb 2024
BH1	2.6m	1.65m	1.25m	0.80m	0.85m
BH2	3.2m	1.50m	1.50m	1.20m	1.20m
BH3	-	1.40m	1.24m	0.70m	0.70m

Groundwater levels appear to have risen since the well pipes were installed at the end of 2022, with a significant rise between January and February of this year. This shows that the groundwater has risen above the top of the river terrace deposits and into the Langley Silt.

Identifiable water-borne contamination such as plumes of fuel oil or chlorinated solvents below the paint shops were not found at the site. Given the presence of the Langley Silt above the aquifer gravel and chalk, this site was not identified as being a risk to groundwater and sampling and testing of groundwater was not carried out.

3.7 Soil Sampling and Analysis

3.7.1 Insitu Analysis

Elevated lead concentrations were previously detected in laboratory analysis of samples as well as insitu with a metals analyser (XRF or X-Ray Fluorescence). This analyser was used again to test the soils exposed by the demolition work, below buildings as well as hardstanding.

3.7.2 Sampling

Hotspots of lead contamination were detected insitu and one was targeted, but there were no signs of contamination such as fuel or solvent stains, emulsified oil or buried waste. No further areas could therefore be targeted for sampling.

On this basis three samples were taken from the surface soils which underlay the tyre shop, one of these (Tyre 3) was from the location (XRF1) where the highest insitu lead concentration had been detected. A single sample was recovered from the footprint of the bungalow and two were recovered from the footprint of the paint shop.

4.0 Contamination Analysis

4.1 Samples of Soil (& Soil Like Material)

The samples recovered at this site were placed in laboratory supplied containers suitable for the proposed analysis.

Where Hydrocarbons especially volatiles are to be assessed, glass jars and vials are used and the samples are placed in a cool box with ice packs and kept at a temperature below 9 degrees C for transport to the laboratory.

Holding times for samples are also applicable since some contaminants can degrade quickly once sampled. This is of great concern with regard to samples of groundwater or surface water. No deviating samples were noted by the laboratory indicating that the samples arrived sealed, at a temperature below 9°C and within sufficient time.

All laboratory work is carried out by a UKAS accredited MCERTS laboratory firm. The laboratory certificates referenced EMT-24/2707 and EMT-24/3251 are appended. The results of the phase 2 soil analysis (EMT-22/20491 and EMT-22/21218) are also presented.

4.2 Scheduled Analysis

Lead is the main contaminant of concern at this development site hence the use of an insitu metals analyser. Although the analyser considered a list of 34 elements, the analysis was set up solely for stable lead readings. The stability of the readings for the other elements were not checked and although the lead error values had stabilised before each test was terminated, it is not known if this was the case for the other elements.

Most of the samples were tested for a broad suite of commonly occurring typical industrial contaminants comprising a basic list of toxic metals including Lead and Chromium, as well as a list of tarry carcinogenic hydrocarbons associated with combustion residues and coal tars (PAH).

Petroleum hydrocarbons were assessed given the presence of old vehicle workshops and some limited semi-volatiles analysis (SVOC) given the finding of dark smeared soils at the location where the sample Paint Shop 2 was recovered. Volatiles were not considered to be present on the basis of olfactory evidence however, the use of the building as a paint shop suggested other light hydrocarbon compounds.

Lastly asbestos given its historic presence on the site in roof boards and anecdotal evidence of buried asbestos waste below the frontage to No. 4 Send Road.

4.3 Assessment Methodology

4.3.1 Generic Assessment Criteria

The measured concentrations of the selected soil contaminants were assessed against published guideline values for the protection of human health within generic exposure scenarios. Various guidelines are applicable all based on various revisions of the Environment Agency CLEA model.

The Environment Agency produced soil guideline values or SGVs for a limited number of contaminants, the model was then taken up by the Chartered Institute of Environmental Health and Land Quality Management Ltd. (CIEH/LQM) who produced guideline values for a large list of contaminants presented in their S4UL publication (Copyright Land Quality Management Ltd. reproduced with permission Publication Number S4UL3813, All rights reserved).

The Department for the Environment Farming and Rural Affairs (DEFRA) also used a modified version of the CLEA model to provide guideline values for a very limited number of contaminants using a revised version of the model which introduced a new 'lower level of toxicological concern' as set out in their SP1010 C4SL report. The most notable contaminant in the DEFRA publication is Lead which was not considered by the Environment Agency or the Chartered Institute of Environmental Health and Land Quality Management.

4.3.2 Exposure Scenario

The proposed development layouts supplied to Sackedgate Ltd show that the area of Nos.2 to 4 Send Road will be covered by dwellings with individual gardens. The area of the paint shop and bungalow at 389-389A Gosbrook Road will be covered by a single building of apartments with off street parking. No gardens are proposed but some simple landscaped areas are to be provided.

For assessment of measured soil concentrations, the generic exposure scenario for residential gardens where home grown produce would be grown and consumed by the new site residents, has been selected for the area of Nos.2 to 4 Send Road.

The generic exposure scenario for residential gardens where home grown produce would not be grown and consumed by the new site residents has been selected for the paint shop and bungalow at 389-389A Gosbrook Road.

4.4 Comparison of Measurements with Guideline Values

The measured values from the samples collected on the site and the measured values from insitu analysis has been compared with the guideline values for the generic exposure scenario set out above.

4.4.1 Metals

The preceding phase 2 investigation included laboratory as well as insitu XRF testing. This showed that elevated concentrations of lead, exceeding the guideline value for this metal in all residential settings (200mg/kg), were present in 3 of 15 samples from the site.

The elevated concentrations were all found in the shallow topsoils and made ground. Lead was only detected at trace concentrations (7mg/kg) in the underlying natural deposits consistent with this metals natural occurrence. There were no exceedances of other metals highlighted by the preceding analysis.

The average of all phase 2 laboratory and XRF analysis for lead was 183mg/kg and the highest lead concentration measured was 508mg/kg. The average of the lead concentrations in just the topsoil and made ground was 250mg/kg.

Once the hardstanding and foundations had been removed, the phase 3 XRF and laboratory analysis of the soils from beneath the buildings has revealed very similar lead and other metal concentrations. The average of the phase 3 XRF analysis for lead was 233mg/kg and the highest lead concentration measured was 538mg/kg.

4.4.2 Poly-cyclic Aromatic Hydrocarbons or PAH

The analysis of all samples included an assessment of these tarry hydrocarbons which comprise fused hexagonal rings of carbons (a single ring forms the compound Benzene). Each different PAH compound has a different number and arrangement of these rings.

Petrogenic PAH compounds can be present naturally as coal tars in coal measures or tars in crude oil. Pyrogenic PAH compounds are created by low temperature low oxygen availability combustion where instead of completely oxidising, clusters of hydrocarbon (benzene) rings can form. Phytogenic PAH compounds are created by plants such as pine or lavender for example and can be extracted in a retort for use a solvent (Turpentine).

PAH compounds are common contaminants in the UK and a group of 16 of the most toxic or the most prolific have been selected for analysis.

Concentrations exceeding the guideline values (CIEH S4UL) were detected in four samples from the preceding phase 2 investigation where excessive concentrations of Dibenzo(ah)anthracene Benzo (a) pyrene and Benzo(b)fluoranthene were detected.

The phase 3 analysis has revealed an exceedance of solely Dibenzo(ah)anthracene in one of the samples from below the tyre shop (ref Tyre3) Although elevated the concentrations of these compounds in the other two samples were just within acceptable limits for that area.

The samples from the garden of the bungalow at No.2 Send Road and from below the paint shop and bungalow at 389-389A Gosbrook Road showed far lower concentrations of these compounds which were well within limits for any residential development.

4.4.3 Additional Phase 3 Semi Volatiles Analysis.

PAH compounds above are part of a wider group of semi volatile organic compounds (SVOC) and a number of these compounds featured in the conceptual model for a paint shop. Volatile organic compounds (VOC) were not detected in samples of the underlying gravels during the phase 2 investigations. Given the absence of any of the strong odours of volatile hydrocarbons, the blackened soil seen below the paint shop and bungalow at 389-389A Gosbrook Road was scheduled for SVOC analysis.

The analysis revealed methyl naphthalene, a poly cyclic aromatic hydrocarbon or PAH as well as carbazole and dibenzofuran both heterocyclic aromatic hydrocarbons.

Carbazole and dibenzofuran are considered potentially persistent, bio-accumulative and can occur alongside pyrogenic PAH compounds in combustion residues such as cigarette ash, furnace ash, vehicle exhausts etc. The concentrations were at µg/kg levels and their human health effects alongside the other PAH compounds detected at mg/kg levels is likely to be marginal, particularly in comparison with benzo pyrene and dibenzo anthracene.

4.4.4 Petroleum Hydrocarbons

In the first instance the analysis has included a basic hydrocarbons test where the total value is divided into weight bands between carbon chain length ranges of C₈ and C₃₅. This analysis does not split the band totals into their aliphatic (open ended chain molecules) or aromatic groups (clustered ringed molecules). Nor does this analysis consider fractions lighter than C₈. The guideline concentrations however, do split the band totals into their aliphatic or aromatic groups and consider fractions between C₅ and C₈.

The aromatics have the lowest acceptability limits and if the unsplit band totals are lower than the limits for the Aromatic or Aliphatic bands, the split values would not exceed the limits either. If the measured concentrations in any one band exceed the limits for that aromatic band, then more detailed analysis will be required that does split the hydrocarbon band totals into the aliphatic or aromatic groups.

As found during the phase 2 investigations, the analysis of the samples recovered from this site has not revealed any petroleum hydrocarbon concentration in any one band that exceeded limits for aliphatic or aromatic hydrocarbons in the respective bands for residential gardens.

The phase 2 report showed that elevated petroleum hydrocarbon concentrations were found in a number of samples of the upper layer of dark grey brown ashy gravelly sand with brick fragments. The measured values were seen to comprise traces in the C₁₆ to C₂₁ range with a bulk in the C₂₁ to C₄₀ range. Diesel fuel, the most persistent of the vehicle fuels, would be expected to show high values in the bands across the C₁₀ to C₂₁ range. The samples with the highest concentrations in the C₂₁ to C₄₀ range corresponded with the samples with the highest concentrations of tarry PAH compounds.

The analysis of the samples recovered from this site has not revealed any concentration in any one band that exceeds limits for aliphatic or aromatic hydrocarbons in the respective bands for residential gardens. Further detailed analysis of these samples is not considered necessary.

4.4.5 Asbestos

The previous phase 2 analysis did not reveal the presence of asbestos fibres or asbestos containing materials in any of the samples recovered from the site. Inspections during and post demolition did not reveal any evidence for any asbestos containing materials in the ground.

The phase 3 analysis however, has revealed the presence of chrysotile asbestos fibre bundles in two of the six samples of surface materials previously covered by buildings. Quantification tests have been carried out on these two samples (Tyre1 & Garden1) revealing quantities of less than 0.001% in both samples.

The CIRIA C733 (Asbestos In Soil And Made Ground) respirable fibre exposure estimate (Section 13.4 of that publication) was carried out for a sandy soil with chrysotile asbestos at a concentration of 0.001%. A number of conservative assumptions have been used such as the sandy soil type, gardening activities being carried out all weekend and every weekend with dry soils being thrown into the air for prolonged periods.

Using the risk table presented in CIRIA C733 (after Hodgson and Darnton, 2000) we can see that the calculated cumulative exposure (fibre/ml.years), based on the 0.001% quantity was considered insignificant with respect to Mesothelioma. For Lung Cancer (table 14.3), the calculated cumulative exposure (fibre/ml.years) based on the 0.001% quantity was a factor of 10 lower than the '*probably insignificant*' risk level.

With respect to the Control Of Asbestos Regulations (CAR 2012) and the HSE approved CAR Soil (2012) guidance published in conjunction with the Joint Industries Working Group and CL:AIRE, their receptor ranking and work categories decision support tool was used to assess remedial works / construction work with respect to licensable or notifiable circumstances and to evaluate the risk to new occupants.

The receptor risk ranking tool showed that these fibre concentrations posed negligible risk. The decision support tool for work categories showed that CAR2012 does not apply to excavation and works on this site. Although not flagged by this software, it is recommended that dust suppression should be available.

If any asbestos containing materials are found in pockets, which were missed by the boreholes and not seen during the demolition process inspections detailed in this report, work should be halted before any fibres can be spread around the surface or become liberated to the atmosphere.



4.5 Summary of Assessment

The suites of metals, combustion residues, fuels, and asbestos considered in the analysis indicated that the dark grey brown topsoil layer present over most of the site contained variable but unacceptable concentrations of lead and PAH compounds. On this basis these soils would not be considered appropriate at the surface of a residential development. Traces of asbestos fibres were found but at the concentrations detected, the risks to new residents appears to be insignificant.

The dark ashy soil is not thought to be the source of the asbestos fibres, it is suspected that the fibres originated in a small pocket where asbestos cement roof board fragments were buried in the area of the former tyre shop. It should also be noted that the sample recovered from garden of No.2 Send Road was very close to the location of the asbestos skip used for removal of the asbestos cement roofs from the buildings on site.

5.0 Conceptual Model

The conceptual model from the preceding Desk Study report has been expanded in the following sections and re-examined on the basis of the phase 3 physical investigations carried out.

5.1 Made Ground On-Site

Location	Associated Contaminants	Dismissed?	Migration Pathway	Dismissed?	Absorption Pathway	Dismissed?	Receptor	Dismissed?
Whole Site	Lead, Cadmium, Chromium, Nickel, Zinc Combustion Residue & coal associated PAH compounds & Cyanides. Asbestos Organic matter in the process of decay and generating CO ₂ above groundwater and CH ₄ H ₂ S below groundwater.	No Dark ashy surface layer found to contain unacceptable concentrations of Lead and PAH compounds.	Present at surface on site.	No	Ingestion of Soil and dust	No (60% pathway contribution for Lead and 80-85% contribution for PAH) (CIEH/LQM 2015 Table 18-60 to 18-64 & CLEA 1.071)	Construction Workers.	No Dermal and inhalation exposure pathways for lead and PAH have minimal contributions. However, asbestos fibres liberated during excavation work poses a risk. Dust control will be required
			Migrating off site via the surface or via porous soils	Yes This soil has been present since at least the 1930s. Most mobile fractions are now absent.	Consumption of homegrown produce and attached soil	No (40% pathway contribution for Lead in veg and attached soil) PAH pathway contributions vary between species. 10.7% for Benzo(b)fluoranthene (detected) 6.4% for Dibenzo(ah)anthracene (detected) (CIEH/LQM 2015 Table 18-60 to 18-64)	Service and Maintenance Workers	
					Dermal contact indoor	Yes Dermal uptake of Lead excluded as significant pathway contributor (0%) in CLEA 1.071 Dermal contribution for elevated PAH individuals 2.0% for Benzo(b)fluoranthene (detected) 2.1% for Dibenzo(ah)anthracene (detected) (CIEH/LQM 2015 Table 18-60 to 18-64)	Site Occupiers	Yes
					Dermal contact outdoor	Yes Dermal uptake of Lead excluded as significant pathway contributor (0%) in CLEA 1.071 Dermal contribution for elevated PAH individuals less than 3% contribution (CIEH/LQM 2015 Table 18-60 to 18-64)	Wider public	Yes However, dust control and surface water flooding controls will be required
					Inhalation of Dust Indoor	Yes 0.21% Inhalation contribution for Lead Max 0.2% contribution for PAH16 (CIEH/LQM 2015 Table 18-60 to 18-64)	Groundwater	Yes
					Inhalation of Dust Outdoor	Yes 0.0 % Inhalation contribution for Lead Max 0.2% contribution for PAH16 (CIEH/LQM 2015 Table 18-60 to 18-64)		
					Inhalation of Vapour Indoor	Yes 0.0 % contribution for Lead Max contribution from PAH16 is 23% for Naphthalene (not detected). <0.1% for Benzo(b)fluoranthene (detected) <0.1% for Dibenzo(ah)anthracene (detected) (CIEH/LQM 2015 Table 18-60 to 18-64)		
					Inhalation of Vapour Outdoor	Yes 0.0 % contribution for Lead 0.0% for Benzo(b)fluoranthene (detected) 0.0% for Dibenzo(ah)anthracene (detected) (CIEH/LQM 2015 Table 18-60 to 18-64)		
					Groundwater	Yes This soil has been present since at least the 1930s. Most mobile fractions are now absent.		

5.2 Stables & Kitchen Gardens to Ivy Cottage Farmhouse

Location	Associated Contaminants	Dismissed?	Migration Pathway	Dismissed?	Absorption Pathway	Dismissed?	Receptor	Dismissed?
Whole Site	Arsenic, Lead, Chromium Combustion Residue (Pyrogenic) PAH compounds	Yes The dark ashy surface layer of soil at the was seen to contain unacceptable concentrations of Lead and PAH compounds. Elevated concentrations of Arsenic and Chrome attributable to this land use were not detected. The source of this layer is unclear and could be attributed to this land use or the soil may have been imported. However, for the purposes of assessment that soil layer is considered to be made ground and have been assessed under the previous linkage.	Present at surface on site.	<u>Yes</u> Source dismissed	Ingestion of Soil and dust	<u>Yes</u> Source dismissed	Construction Workers.	<u>Yes</u> Source dismissed
			Migrating off site via the surface or via porous soils	<u>Yes</u> Source dismissed	Consumption of homegrown produce and attached soil	<u>Yes</u> Source dismissed	Service and Maintenance Workers	
					Dermal contact indoor	<u>Yes</u> Source dismissed	Site Occupiers	<u>Yes</u> Source dismissed
					Dermal contact outdoor	<u>Yes</u> Source dismissed	Wider public	<u>Yes</u> Source dismissed
					Inhalation of Dust Indoor	<u>Yes</u> Source dismissed	Groundwater	<u>Yes</u> Source dismissed
					Inhalation of Dust Outdoor	<u>Yes</u> Source dismissed		
					Inhalation of Vapour Indoor	<u>Yes</u> Source dismissed		
					Inhalation of Vapour Outdoor	<u>Yes</u> Source dismissed		
					Groundwater			

5.3 Workshop, Garage & Paint Shop (389 Gosbrook Rd)

Location	Associated Contaminants	Dismissed?	Migration Pathway	Dismissed?	Absorption Pathway	Dismissed?	Receptor	Dismissed?
Northern side of site	Vehicle Maintenance Gasoline C5 to C12 hydrocarbons Diesel C12 to C35 hydrocarbons, Used Engine oil C21 to C40 hydrocarbons, pyrogenic PAH and Cyanides Car battery Lead Spray Painting Cadmium, Lead, Chromium VI paint pigments. Spray on cold Zinc galvanising. Solvents such as Toluene, trichloroethylene turpentine among others	<u>Yes</u> Although two different types of former activity were identified for this workshop, no evidence was found in the boreholes and pits for widespread plumes of contamination with the identified metals, fuels lubricants or solvents. Subsequent inspections insitu testing and sampling for laboratory analysis have not identified any of the identified contaminants	Present at surface on site. Migrating off site via the surface or via porous soils	<u>Yes</u> Source dismissed <u>Yes</u> Source dismissed	Ingestion of Soil and dust	<u>Yes</u> Source dismissed	Construction Workers.	<u>Yes</u> Source dismissed
					Consumption of homegrown produce and attached soil	<u>Yes</u> Source dismissed	Service and Maintenance Workers	
					Dermal contact indoor	<u>Yes</u> Source dismissed	Site Occupiers	<u>Yes</u> Source dismissed
					Dermal contact outdoor	<u>Yes</u> Source dismissed	Wider public	<u>Yes</u> Source dismissed
					Inhalation of Dust Indoor	<u>Yes</u> Source dismissed	Groundwater	<u>Yes</u> Source dismissed
					Inhalation of Dust Outdoor	<u>Yes</u> Source dismissed		
					Inhalation of Vapour Indoor	<u>Yes</u> Source dismissed		
					Inhalation of Vapour Outdoor	<u>Yes</u> Source dismissed		
					Groundwater			

5.4 Workshop, Tyre Fitters & Printers (No.4 Send Road)

Location	Associated Contaminants	Dismissed?	Migration Pathway	Dismissed?	Absorption Pathway	Dismissed?	Receptor	Dismissed?
Southern side of site	Vehicle Maintenance Gasoline C5 to C12 hydrocarbons Diesel C12 to C35 hydrocarbons, Used Engine oil C21 to C40 hydrocarbons, pyrogenic PAH and Cyanides Car battery Lead Printers Cadmium, Lead, Chromium pigments Phthalate dye carriers Methyl Ethyl Ketone, Acetone, Isopropyl Alcohol type solvents Potassium Hydroxide activator (high pH) Acids to neutralise activators (low pH) Tyre Fitters Pyrogenic PAH compounds from burned refuse Inc tyres & inner tubes. Gas generating gypsum in refuse plasterboard metals from corroding scrap Zinc and Cadmium from vulcanised rubber.	<u>Yes</u> <i>No evidence was found in the boreholes and pits for widespread plumes of contamination with the identified metals, fuels lubricants or solvents.</i> <i>Subsequent inspections insitu testing and sampling for laboratory analysis have not identified any of the identified contaminants</i>	Present at surface on site.	<u>Yes</u> Source dismissed	Ingestion of Soil and dust	<u>Yes</u> Source dismissed	Construction Workers.	<u>Yes</u> Source dismissed
			Migrating off site via the surface or via porous soils	<u>Yes</u> Source dismissed	Consumption of homegrown produce and attached soil	<u>Yes</u> Source dismissed	Service and Maintenance Workers	
					Dermal contact indoor	<u>Yes</u> Source dismissed	Site Occupiers	<u>Yes</u> Source dismissed
					Dermal contact outdoor	<u>Yes</u> Source dismissed	Wider public	<u>Yes</u> Source dismissed
					Inhalation of Dust Indoor	<u>Yes</u> Source dismissed	Groundwater r	<u>Yes</u> Source dismissed
					Inhalation of Dust Outdoor	<u>Yes</u> Source dismissed		
					Inhalation of Vapour Indoor	<u>Yes</u> Source dismissed		
					Inhalation of Vapour Outdoor	<u>Yes</u> Source dismissed		
					Groundwater			

5.5 Forge

Location	Associated Contaminants	Dismissed?	Migration Pathway	Dismissed?	Absorption Pathway	Dismissed?	Receptor	Dismissed?
35m east	Pyrogenic PAH Arsenic (from Cornish pig iron), Lead, Copper Zinc	No The area of this suspected old forge could not be investigated. The presence of contamination at that location cannot be proven or dismissed. The dark ashy surface layer of soil at the was seen to contain unacceptable concentrations of Lead and PAH compounds. The source of this layer is unclear however the contaminants detected could be attributable to ash imported from this forge to dress pathways or condition soil or provide potash. However, for the purposes of assessment, the ashy soil layer is considered to be made ground and the detected contaminants have been assessed under the made ground linkage.	Leached, onto site surface area by groundwater through porous soils	<u>Yes</u> Groundwater and surface water flow from the Gosbrook House location is south eastward and away from site. The ash in the ashy soil on site may have originated from the forge however, the detected contaminants are considered in the made ground linkage	Ingestion of Soil and dust	<u>Yes</u> Migration pathways dismissed	Construction Workers.	<u>Yes</u> Migration pathways dismissed
			Leached, onto site surface area by surface water flow		Consumption of homegrown produce and attached soil	<u>Yes</u> Migration pathways dismissed	Service and Maintenance Workers	
			Direct migration of volatiles/gasses onto site surface area through porous soils.		Dermal contact indoor	<u>Yes</u> Migration pathways dismissed	Site Occupiers	<u>Yes</u> Migration pathways dismissed
			Surface contaminants trafficked onto site		Dermal contact outdoor	<u>Yes</u> Migration pathways dismissed	Wider public	No
			Airborne dust containing contaminants or fibres		Inhalation of Dust Indoor	<u>Yes</u> Migration pathways dismissed	Groundwater	No
			Gas Migration through porous soils	No The area of this old forge could not be investigated.	Inhalation of Dust Outdoor	<u>Yes</u> Migration pathways dismissed		
			Directly to groundwater		Inhalation of Gas or Vapour Indoor	<u>Yes</u> Migration pathways dismissed		
			Direct migration of fluids/volatiles/gas ses from source area through porous soils onto other land.		Inhalation of Gas or Vapour Outdoor	<u>Yes</u> Migration pathways dismissed		
					Groundwater & Other Land			

6.0 Conclusions on the Source-Pathway-Receptor Model

Previously the conceptual model in the phase 2 report indicated a number of plausible linkages between contaminant sources and vulnerable receptors. Some linkages were provisionally dismissed subject to investigation of the soils which lay below buildings and hardstanding at that time.

The phase 3 investigations of the previously covered ground have not revealed any plumes of fuel, paints, solvents or other identifiable contamination. The dark ashy surface soil layer seen around the buildings, was also present below the buildings and hardstanding. Insitu and laboratory analysis has shown that similar concentrations of lead and tarry PAH compounds are present in these soils.

Chrysotile asbestos fibres were detected in two of six samples of the surface soils left behind after demolition and site clearance. The fibre quantification tests carried out showed very low concentrations of 0.001% in both samples. Respirable fibre estimates suggests that the risk were insignificant however, asbestos has remained as a possible linkage.

The dark grey brown ashy surface soil and immediately underlying made ground is not considered to be suitable in a residential setting, especially in gardens where produce could be grown, but also in residential landscape type areas.

The lead and PAH compounds have been present for a very long time and any soluble or mobile fractions would be expected to have migrated away a long time ago. Asbestos fibres pose no risk while they remain in the ground and not exposed to the atmosphere.

Given the expected absorption pathways for lead and PAH compounds, these soils could remain below buildings and hardstanding which is not permeable. For permeable paving solutions, leachate tests (preferably the NRA preparation method which aims to mimic the effects of rainfall) would be required to see if the lead and PAH compounds could be mobilised by concentrated water flow.

The workforce involved in earthworks at this site and the wider public are at risk from dust containing lead, PAH compounds and possibly asbestos, that are liberated during any earthworks or site clearance.

7.0 Recommendations

7.1 Further Investigations

As discussed in section 3.5, two small areas remain uninspected, the first is covered by shipping containers adjacent to Send Road. The second area is a small section of ground adjacent to Forge Close which was used by the demolition contractors as an access point.

Both areas will need to be carefully examined, possibly using a small excavator. If asbestos cement roof board fragments are found in the ground adjacent to Send Road, or if a silt filled soakaway is found adjacent to Forge Close, remedial works may be required to remove any unacceptable materials. The scope of these works, if even required, is unknown at this time.

Most of the site area was seen during the removal of hardstanding to be underlain solely by the dark grey brown ashy surface soil layer and some made ground below that. Further investigations are not considered necessary. If ground conditions are disclosed that differ from those described above, work should be halted and Sackedgate Ltd notified to assess the situation and devise measures if necessary to deal with the unexpected findings.

This may be on discovery of concrete, brick or metal structures in the ground, inclusions such as buried asbestos roof board, large amounts of rubble, scrap metal, timber, crockery or hearth ash. This would also include any plumes of fuel or oil from vehicles, even just discoloured, odorous or suspicious ground conditions that are discovered on the development site.

Dust suppression measures should be made available and the conditions on site monitored. If at any time the ground conditions and in particular materials planned to be excavated become dry, dust suppression should be applied. This is normally achieved simply with hoses or sprinklers. Care should be taken to ensure that these measures do not cause runoff or oversaturate material being taken away from the site.

7.2 Remedial Works

At this stage, the only works required to make this site suitable for habitation is the removal of the dark grey brown ashy surface soil layer and immediately underlying made ground. The made ground is characterised by the presence of brick fragments and a darker colour than the Langley Silt below. Contamination was not found by any of the exploratory holes into the deeper soils. These excavations will only be required in proposed garden and landscaped areas. The soils could remain below permeable paving if leachate tests indicate immobile lead and PAH compounds.

Any excavation or handling of the dark grey brown ashy surface soil layer should only be carried out in damp conditions to minimise dust liberation. If works are proposed in the drier summer months, dust suppression as described above, should be carried out.

7.3 Surplus Soil

The arisings from all excavations must be segregated to ensure that the contaminated dark grey brown ashy surface soil layer or made ground are not stockpiled with any arisings of the underlying natural Langley Silt (orange brown gravelly sandy clay) or the river terrace deposits (gravelly sand) below the Langley Silt. Foundation arisings of natural soils should be reused on site wherever possible.

The contaminated surface materials need to be removed from the development site however, its route via the normal hierarchy of 1) re-use, 2) treatment and recycling and 3) disposal has not been defined. This may need some further analysis depending on the requirements of the materials haulier.

The average lead and average PAH values are a good indication of the concentrations in any final stockpile of the excavated upper dark layer of topsoil and underlying made ground. Considering these averages it can be seen that this soil is not acceptable in a residential setting where homegrown produce would be consumed by the residents, or in an allotment setting.

The dark grey brown ashy soil and immediately underlying made ground could be re-used directly in residential settings where produce would not be grown, in parkland areas, in landscape areas or on commercial/industrial land developments. Some validation tests would be required to show that the soil was well mixed and didn't contain any hotspots.

The selected contaminants were not seen in samples of the underlying natural deposits. These soils are not considered to be contaminated and could be re-used in most land use scenarios, including residential and allotments.

Treatment and recycling of the upper dark layer of soil and underlying made ground would need to reduce the lead concentrations and specialist analysis would be required to define the actual lead compounds present. Given the re-use options available, treatment and recycling may not be economic however, this would need to be confirmed by any treatment and recycling facility that propose to accept the soil.

7.4 Soil Disposal to Landfill

Direct disposal to landfill will require formal waste acceptance criteria (WAC) tests which have not been carried out. WAC analysis of samples from the ground will probably not provide an accurate representation of the soils that will eventually be stockpiled for removal. Inevitably hotspots will be missed or over-included in any waste classification based on those results. Ideally samples intended for waste acceptance criteria (WAC) classification should be taken once the soil is stockpiled after initial segregation. The act of excavation transport and then stockpiling will disperse any hotspots and generally mix the soil.

At this stage however, it can be seen that the PAH compound concentrations, petroleum hydrocarbon concentrations were within WAC limits for inert waste. The asbestos quantities were below the 0.1% limit. The solubility/leachability of the lead and other metals has not been assessed nor has the organic matter content and a number of other determinants in the WAC analysis list.

However, this soil layer is very old, soluble lead and PAH compounds are not expected to still be present. Although dark in colour, organic matter was not visible in this old material. On the balance of probabilities, WAC tests on this material once stockpiled, would probably show that the dark grey brown ashy surface topsoil layer and the underlying made ground would be classified as inert waste for landfill acceptance.

The analysis results of samples from the ground may not provide an accurate representation of the soils that will eventually be stockpiled for removal. The soils analysis in this report would be a good start for the haulier to consider the potential removal route for these soils. However, the analysis carried out in this investigation was to provide an assessment of ground conditions and not to provide a waste classification in accordance with the Environment Agency Guidance on the Classification and Assessment of Waste (Technical Guidance WM3 October 2021).

A material movements plan may need to be drawn up in accordance with current guidelines in conjunction with the haulier and recipient of the soil.

7.5 Imported Soils

Any soils imported to the site for making up ground levels or topsoils for dressing garden and landscape areas should be validated to ensure it is fit for purpose. If possible this should be done before the soil is placed in order to avoid having to scrape the material out of gardens if the validation analysis finds contamination. If possible imported soil should be stockpiled temporarily while analysis is carried out.

Topsoils to be used in garden areas or allotments are of most concern and will require validation testing that is independent from the supplier. Quality control analysis carried out by the supplier is generally not accepted by regulators.

7.6 Validation

The local authority will need confirmation that the sensitive areas of the site, where new occupants could come into contact with surface soils, are fit for that purpose. A brief report documenting an inspection and the removal of the made ground which presents photographs of the exposed natural soil should suffice.

The garden areas of the residential units to be constructed on Nos.2 to 4 Send Road should be confirmed to be free of the original surface layer of dark grey brown ashy soil and underlying made ground (brick fragments should be used as a marker). The landscaped areas around the apartment block proposed for 389-389A Gosbrook Road should be inspected in a similar way.

Any remedial works to remove unusual findings or contaminated soils found below the remaining uninspected areas will need to be carefully photographed and documented in a more detailed validation report which includes soil analysis to demonstrate successful remediation.



8.0 Xray Fluorescence Validation



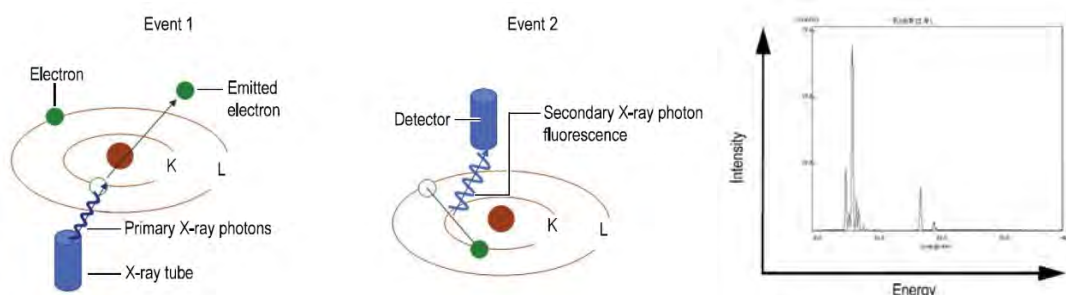
X-Ray Fluorescence analysers allow a lot of measurements for heavy metals to be carried out in one day. This analysis also adds a significant amount of data to any ground investigation about the distribution of the metals over the site in question and if they are present as flakes/fragments or evenly distributed in the soil matrix.

The results of the analysis are available live as the investigation is carried out. This allows for a more concise selection of laboratory analysis before samples are submitted for testing and for fast and effective excavation control.

Some guidance is available for the use of XRF analysers such as the Environment Agency Framework for the Use of Rapid Measurement Techniques (RMT) in the Risk Management of Land Contamination (March 2008), BS EN ISO 13196- Soil Quality — Screening Soils For Selected Elements By Energy-Dispersive X-Ray Fluorescence Spectrometry Using A Handheld Or Portable Instrument (2015) and BS ISO 18227:2014 Soil Quality — Determination Of Elemental Composition By X-Ray Fluorescence.

A new standard is currently being drafted by the British Standards Institute titled BS10177 *Guidance on the Use of [Handheld/Portable] Energy Dispersive X-Ray Fluorescence Spectrometers in Soil and Soil-like Materials Quality Assessments*. Sackedgate Ltd. is the project leader for this new guidance.

8.1 How It Works



The X-Ray Fluorescence Analyser (XRF) exposes insitu soil or samples to a primary X-Ray beam which induces elements to emit or fluoresce an X-Ray in response. Each element fluoresces at a particular point on the detectable X-Ray energy spectrum.

From the peaks in the spectrum the analyser calculates the concentrations of the detectable metal elements that are present.

8.2 Note on the Ionising Radiation Regulations (IRR2017)

The XRF analyser used for parts of this investigation is a source of ionising radiation and subject to the Ionising Radiation Regulations (IRR2017). Although the analyser is designed for handheld use, in order to operate the analyser as safely as is reasonably possible it is mounted on a tripod. This allows the operator to stand clear when it is in use, thus avoiding any X-Ray backscatter and allowing the operator to be recovering or preparing the next sample for analysis while the analyser is performing tests.

Where particular safety requirements need to be implemented such as shielding, personnel barriers at the minimum safe distance (3m), warning signs or tool box talks to site personnel are required, this will be documented and issued as a dynamic risk assessment in accordance with IRR2017 as appropriate and as described in the section below.

8.3 Implemented Safety Measures

XRF Safety signage was put up beside the site safety notices on the site boundary. Testing on the 12th and the 21st of February 2024 was carried out with workforce members present on site.

A brief 'toolbox talk' was given to these personal about X-Ray safety and the need to keep at least 3m distance from the analyser at all times. When personnel enter the 3m exclusion zone, the protocol is to shut off the test in progress however, such action was not required on either day.

Care was taken at the site boundaries to ensure that a 3m safe distance was maintained from any boundary.

8.4 Homogeneity

The analyser has a narrow primary X-Ray beam (3mm) and by mounting the analyser on a tripod, it is possible to take a number of readings very close together over a very small area. This shows if the metals in question are homogenous throughout the soil mass or if the metals are present as individual grains or flakes.

8.5 Limitations

Some metals like Lead have a uniform fluorescence response for a variety of Lead compounds, some metals however, show variations in the fluorescence response for different compounds of the same metal. Matrix effects can also occur due to atoms in the sample matrix influencing the fluorescence of others, sometimes by absorption or sometimes by enhancement of this fluorescence.

The primary X-Ray beam has an eight position auto selected filter per beam, per mode however, exposure durations at 40kV and then at 8kV are set manually on the basis of obtaining steady measurements for all or just selected metals.

For this investigation, the exposure durations have been set to give the fastest and best results for Lead concentrations only. The measured concentrations of the other metals should therefore be viewed with caution since optimum exposure durations for these metals have not been determined or applied.

For the accurate detection of metals other than Lead, it may be necessary to firstly define suitable exposure times to give steady readings at both 40kV and 8kV and then carry out some XRF trials on samples that are then sent to the laboratory for comparison tests.

The results of the comparisons can then if necessary be fed back to the analyser as a site specific calibration. Other issues can be caused by high water content or high concentrations of organic material. These may need to be addressed by specific sample preparation such as drying the soil or sieving away organic matter and items such as flints.

8.6 Testing Blank

Part of the start-up procedure for the XRF analyser is to 1) test its proximity cut off, 2) to test the Geiger counter and 3) test a sample of known contaminant concentrations. The JRP1 test blank is a mixture of crushed pyrites, galena, barites, all with high metal concentrations such as Copper (44660mg/kg), Nickel (192mg/kg), Arsenic (1327mg/kg) and Lead (387mg/kg). These minerals were selected because of their generally stable nature.

The specimens were powdered, sieved and thoroughly mixed (2 to 1) with plaster of Paris. After thoroughly mixing with water half of the material was pressed into a lens case and half was placed in a pot and sent for laboratory analysis. The hardened material in the lens case is kept with the analyser and tested each time the analyser is used for contaminated land investigations and the laboratory results are available on request.

8.7 Moisture Content

The XRF analyser determines concentrations of various elements as it sees them in a 'wet' state. The concentrations of the elements are subsequently converted into a 'dry' weight concentration when the results are processed. This is carried out using an assumed or measured moisture content, as shown on the results certificate.

For this site, a moisture content of 20% was assumed for the dark upper surface layer and underlying made ground. This was based on the moisture content tests carried out on the laboratory samples. Where a larger than actual moisture content is assumed, the converted concentration result will be higher than the actual concentration present.

8.8 Qualitative or Quantitative

If the analyser is checked against its reference samples and then used insitu without any complementary laboratory analysis, the results should be viewed as qualitative. Such results may be very useful for steering further investigation however, they cannot be used directly in any final assessment.

For quantitative results, a more rigorous approach is required as described below where complementary laboratory analysis is used to validate the XRF analysis results.

8.9 Validation Laboratory Analysis

Quantitative assessment require validation against complementary test methods. UK Government guidance in the LRCM (Land Contamination Risk Management) System states the following:

All of your laboratory monitoring data should be derived from methods that are accredited to the MCERTS soil monitoring performance standards

<https://www.gov.uk/government/collections/monitoringemissionsto-air-land-and-water-mcerts#soil-monitoring-performance-standards>).

MCERTS accreditation can also apply to in situ testing and rapid measurement techniques. You can still use in situ testing and rapid measurement techniques that do not have MCERTS accreditation if you can meet our requirements.

If the rapid measurement technique method has MCERTS accreditation we will accept the results without any further laboratory testing. If the rapid measurement technique method does not have MCERTS accreditation please provide:

- *Complementary MCERTS accredited laboratory analysis for an appropriate proportion of the results*
- *Evidence of training for those who carry out the on-site measurements*
- *Evidence of quality control and equipment calibration procedures*

Where the concentration range for any particular metal contaminant is unknown, a validation frequency of 20% laboratory comparisons will be assumed, as set out in the EA Framework for the Use of Rapid Measurement Techniques (March 2009).

However, where the onsite result is within +/-30% of the guideline limit for that contaminant, 10% of samples analysed are sent to the laboratory. Outside the +/-30% range, a validation frequency of 2% laboratory samples could be used.

Given the difference between measured Lead values averaging 233mg/kg and a highest value of 538mg/kg and the selected guideline value of 200mg/kg for Lead (DEFRA SP1010 C4SL), a 15% validation figure was considered appropriate for the 21 insitu exposures that were carried out.

8.10 Laboratory VS XRF Analyser Comparisons

The comparison of laboratory and XRF analyser results is presented below. The plots compare the XRF results with the laboratory for the selected samples. An ideal 1:1 line is shown and an overall trend line for the data is also presented as a dotted line.

8.10.1 Note on the Accuracy of Laboratory Methods

Extract from BS ISO 15176:2018 –

Total concentrations of potentially harmful elements are the total of the element present in all chemical forms and irrespective of its location in the soil material, including that incorporated into silicate minerals.

Determination of these “true” total concentrations requires use of an instrumental technique such as X-Ray fluorescence analysis or a powerful solvent combination, such as a mixture of hydrofluoric and perchloric acids.

The use of this solvent presents many practical problems and for many purposes in environmental assessment, pseudo-total concentrations suffice. These are determined using a strong acid or combination of acids, but they typically leave a small insoluble residue with some soil materials.

Depending on the element and the matrix, these typically yield about 70 % to 90 % of the “true” total concentration (it can be lower for those elements which are present predominately bound in silicate or aluminate lattices). When comparisons with guideline values are required for particular soil uses, it is essential to determine whether “pseudo-total” or “total” concentrations are required.

8.11 Comparison for Lead

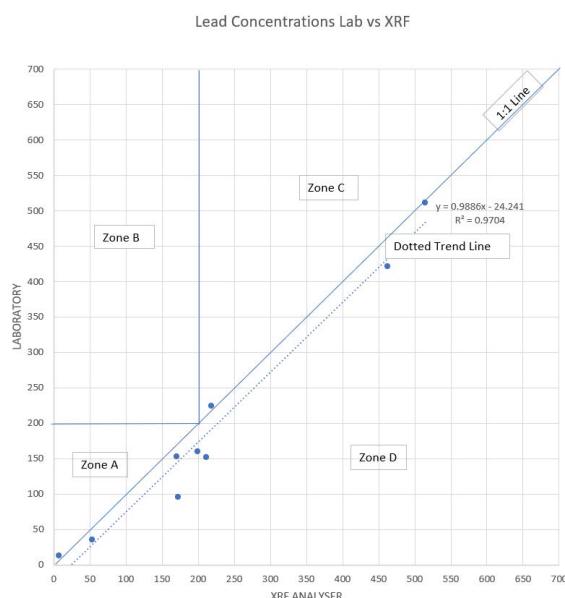
The comparison of laboratory and XRF analyser results is presented below.

Lead Concentrations XRF vs Laboratory						
Insitu XRF Exposure Ref	Insitu XRF Result (mg/kg)	Sample Ref	Sample XRF Exposure Ref	XRF Sample Result (mg/kg)	XRF Sample Average (mg/kg)	Laboratory Sample Result (mg/kg)
		JRP1	4,5	378,391	384.5	387
		WS1-0.3m	6,7,8	204,245,184	211	152
		WS1-0.8m	9,10,11	74,26,58	53	35
		BH1-0.6m	12,13,14	183,170,244	199	160
		WS3- 0.6m	15,16,17	444,434,508	462	421
		WS4-0.4m	18,19,20	142,221,153	172	96
		WS4-0.7m	21,22,23	7,9,6	7	13
XRF5	110	Tyre1	31,32,33	181,172,157	170	153
XRF2	253	Tyre2	34,35,36	281,223,150	218	224
XRF1	354	Tyre3	37,38,39	484,538,520	514	511

XRF values averaged for multiple exposures.
 Laboratory samples sieved (10mm) and mixed. Granular content discarded.
 Lab XRF carried out inside sample pot.
 Suspected Statistical Outlier Values in red

The plot below compares the XRF results with the laboratory results for tests on the same samples. The comparison values from the previous phase 2 investigation are included.

Perfect unity between lab results and XRF results will plot on the 1:1 line and the mathematical trend would be $y=x$ and $R^2=1$. The actual trend is plotted as a dotted line. Ideally the comparison points will plot in a line, along or just below the 1:1 line (XRF overestimation) with an R^2 value as close to 1 as possible.



Zone A of this graph shows where the XRF analyser has underestimated in comparison to the laboratory but without this allowing an exceedance of the critical concentration to go undetected.

Zone B Points in this area show that the underestimates by the XRF analyser will result in exceedances of the critical concentration not being identified by the analyser. Significant points in this area will show that the XRF results are not reliable.

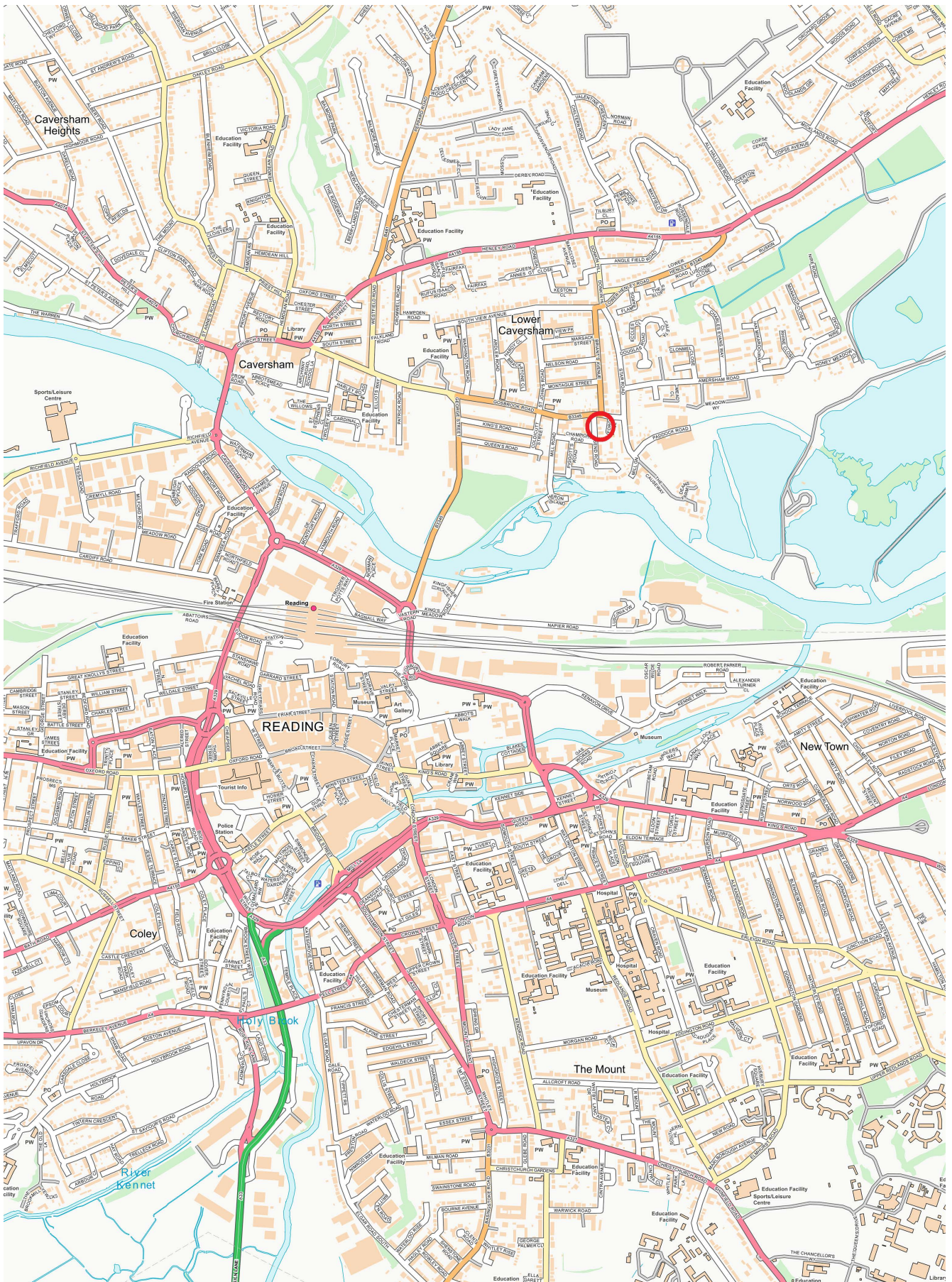
Zone C. This shows where the analyser has underestimated in comparison to the laboratory but has correctly identified an exceedance of the guideline or target value.

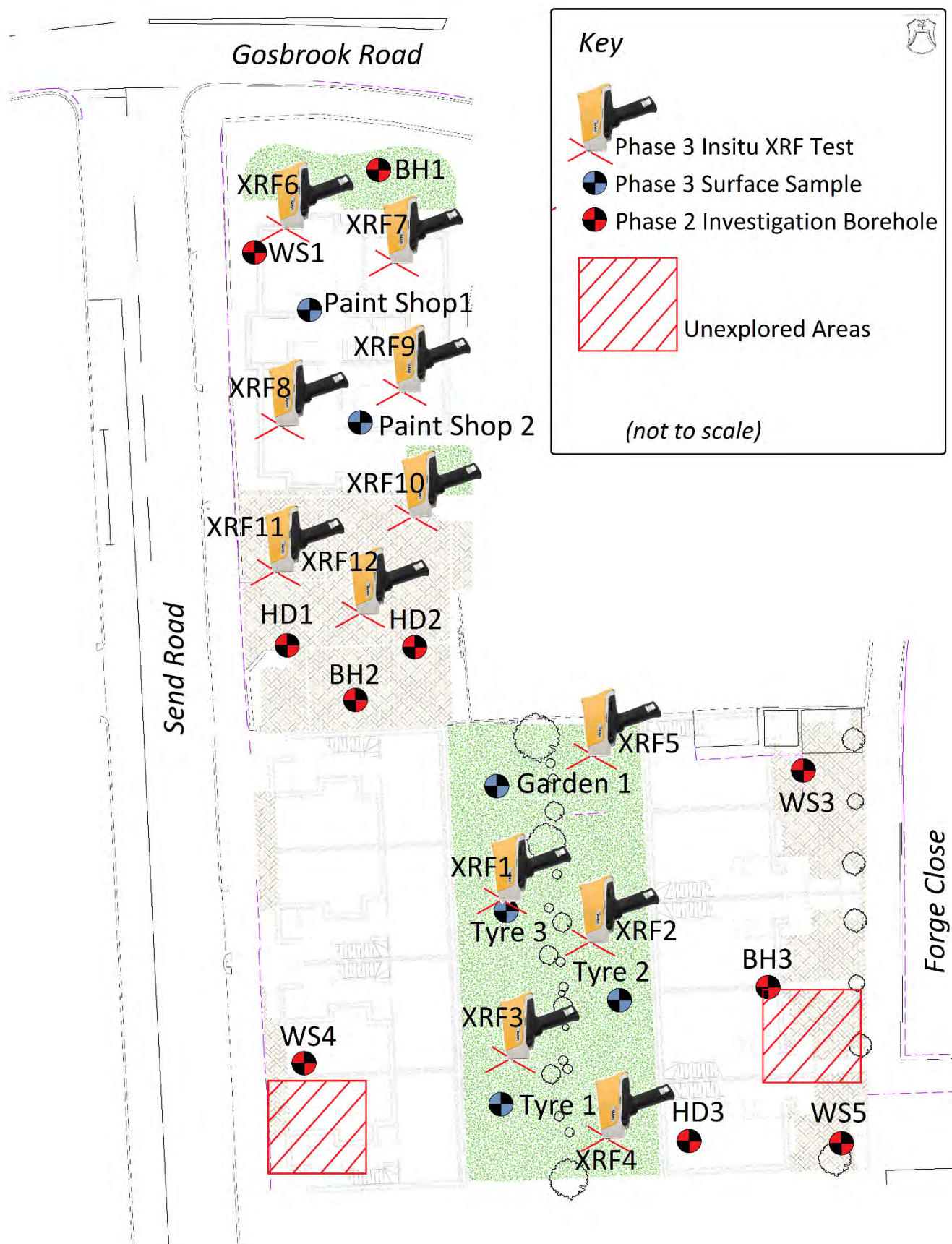
Zone D. This is the preferred zone where the XRF analyser has overestimated in comparison to the laboratory and without an exceedance of the critical concentration going undetected by the analyser.

Underestimations resulting in high readings being deemed acceptable have not occurred in the comparison tests and the R^2 value is 94%. This shows that the analyser has correctly identified increasing concentrations and has on the whole, slightly over estimated the concentrations. On this basis the analyser results for Lead appear to be accurate and reliable.

8.12 Laboratory vs Analyser (Other Elements)

No other comparisons have been carried out between analyser and laboratory at this time. It should be noted that stable readings for lead were obtained, the error values for the other metals were not monitored.







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Revisions 3			

