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I & H BROWN

MAELOR GASWORKS REMEDIATION

VERIFICATION REPORT

14890-REP-001

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Revision History

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1. INTRODUCTION

IKM Consulting Limited (IKM) has been commissioned by I&H Brown Limited (IHB) to act as their designers for the Maelor Works Remediation Project. As part of their project brief, IKM has undertaken an initial site assessment and outline remediation design (as part of the original project tender submission), followed by supplementary site investigations and detailed remediation design work. In conjunction with these works, laboratory trials and specialist treatment design work has been conducted by HBR Limited (HBR) and Geo² Limited (Geo²).

The investigation and design work was used by IHB to produce a programme of remediation works that was agreed with the landowner and client for the project, National Grid Property Holdings Limited (NGPH) and their agent, WorlyParsons Europe Limited (WP). The remediation design was then incorporated into an overall planning application that was lodged with the local planning authority, Wrexham County Borough Council (WCBC). After extensive consultations with other WCBC departments and Natural Resources Wales (NRW), planning permission was granted, with conditions, on 11th February 2015 (Application Ref: P\2014\0658).

The remediation works were carried out by IHB and their appointed sub-contractors between March and July 2015 (final handback 14/7/2015 – Handback documents are contained in Appendix A), with supervision and verification of the works being undertaken by IKM, including a post remediation monitoring round in October 2015 (temporary Gatekeeper access request only).

This Verification Report presents the record of supervision and verification work carried out in order to demonstrate the successful completion of the remediation works. The report references and draws on the site investigations and data assessments which have been reported separately, namely:

- Areas A and C Stage 1 Risk Mitigation Works Factual Report, July 2014, IKM Consulting Limited (IKM REP002 – Doc Ref: 13627-REP-002);
- Risk Assessment and Remediation Design Report, September 2014, IKM Consulting Limited (IKM REP005 – Doc Ref: 13627-REP-005; and



- Garage Investigation Report, November 2014, IKM Consulting Limited (IKM REP006 – Doc Ref: 13627-REP-006).

1.1 Scope

The remediation works at the site were intended to eliminate or mitigate the significant pollutant linkages identified as a result of the previous site investigations and risk assessments and thereby to render the site suitable for its current use as open storage and commercial activities and prevent any ongoing environmental impacts that could lead to intervention by the regulators.

The key objectives of this Verification Report are to:

- Verify that all historical significant free phase tar or other liquid hydrocarbon contamination within the site has been excavated and treated;
- Verify that impacted shallow groundwater associated with the above tar / hydrocarbon contamination and the historical release of water soluble coal gas by-products (ammonia and phenols) has been intercepted and abstracted for treatment and off-site disposal;
- Verify that tar/liquid hydrocarbon contaminated sediments have been removed from the site surface water drainage system and the surface water bodies into which the drains discharge;
- Verify that all excavated soils and sediments have been treated appropriately to produce materials that are suitable for use as excavation backfill and do not present a significant risk to shallow groundwater / surface water at the site boundary or to site users; and
- Provide a comprehensive record of all remediation work and associated data for use in the future management or redevelopment of the site.

Remediation work at the site was conducted under the terms of the NGPH Remediation Brief for the Maelor Works site (Site Ref. No 138S) and the subsequent contract between NGPH and IHB.



1.2 Summary of Previous Reports

The site has a long history of the investigation and assessment of the impacts and legacy of its former use as a major coal gas manufacturing site. The site has been subject to division into areas of different land ownership; portions of the site are now owned by Wales and West Utilities that were excluded from this phase of investigation and remediation work. The NGPH part of the site has also previously been subject to some remediation work, including the removal of spent oxide waste deposits and the contents of the main tar storage tank.

The current phase of remediation work was initiated by a Stage 1 Risk Mitigation Site Investigation programme that was designed to add to the existing site investigation information base and provide a basis for the remediation design (assuming that the current site use was to continue unchanged).

The Stage 1 site investigations were reported in a series of Factual Reports for different parts of the site: Area AC being the main part of the site within the current site perimeter fence, and Area B West and Area B East being the NGPH landholding beyond the perimeter fence to the west and east of Area AC.

Stage 1 information was added to previous site investigation and monitoring information (provided by NGPH as a Tender Information Package) to allow a detailed risk assessment of the potential pollutant linkages present at the site. The risk assessment work identified a number of viable pollutant linkages that required mitigation / remediation if the site were to continue in its existing use scenario. The necessary remediation design was incorporated into the combined risk assessment and remediation report (IKM REP005), which in turn was submitted as part of the remediation works proposals and associated planning permission.

As a result of the detailed risk assessment, only land within the main works area (Area AC) was identified as requiring active remediation works. Areas B West and East were therefore excluded from the remediation design and remain unaffected by the subsequent remediation works.



Following completion of the main Risk Assessment and Remediation Design Report, the requirement for remediation beneath occupied buildings within Area AC was further investigated and assessed, with this work being reported as a separate supplementary report (IKM REP006). As a result of this work, active remediation beneath occupied buildings was deemed unnecessary and was excluded from the proposed works included in the planning application and associated consultations and licence applications.

1.3 Projects contact list

A listing of key organisations and personnel involved in the Maelor Works Remediation Project is provided in Table 1 below.

Table 1: Project Contact List

Role	Organisation and Address	Position	Name
Client	National Grid Property Holdings Ltd National Grid House Warwick Technology Park Gallows Hill Warwick CV34 6DA	Contact Mobile No	Matt Pearce 07768 036925
		Embedded AOC Mobile No	Sarah Helby 0758 4496003
Principal Contractor	I & H Brown Ltd PO Box 51 Dunkeld Road Perth PH1 3YD	Contract Manager Tel No Mobile No	Alex Mark 01738 637171 07775 818204
		Site Agent Mobile No	Billy Spence 01738 637171
Consultant / Designer	IKM Consulting Ltd Park House 39 Bo'ness Road Grangemouth FK3 9AR	Project Manager Tel No	Liz Copland 01324 878822
		Lead Engineer Mobile No	David Cooke 07966 126240
		Director Tel No	Alistair Kean 01324 878822
CDM Co-ordinator	Parsons Brinckerhoff Manchester Technology Centre Oxford Road Manchester M1 7ED	Contact Tel No	Kevin Jones 0161 200 5000



Role	Organisation and Address	Position	Name
AOC	WorleyParsons Bull Wharf Redcliffe Street Bristol BS1 6QR	Project Manager Tel No Mobile No	Kevin Stone 0117 925 1304 07901 712598
		NEC Project Manager Tel No Mobile No	Allen Murray 0117 925 1304 07867 528 480
Specialist Contractors	Chemical Analysis (Soils and Groundwater) Derwentside Environmental Testing Services Unit 2 Park Road Industrial Estate Consett Co Durham. DH8 5PY	Contact Tel No	Adam Fenwick 01207 582333
	Radiological Survey Aurora Health Physics Services Ltd 3 The Terrace Library Avenue Harwell Oxford Oxfordshire. OX11 0SG	Contact Tel No	Allan May 01235 820049
	Groundwater Abstraction and Water Treatment Geo ² Remediation Ltd Units 7 Ferrybridge Workspace Pontefract Road Ferrybridge. WF11 8PL	Contact Tel No	Adam Wilson 01977 674113
	Soil Stabilisation HBR Ltd Coggeshall Road Earls Colne Essex. CO6 2JX	Contact Tel No Mobile No	Dr Chris Evans 01787 222768 07748 760887



Role	Organisation and Address	Position	Name
	Public Relations JBP The White House 6 Whiteladies Road Clifton Bristol. BS8 1PD	Contact Tel No Mobile No	Matthew Thompson 01179 072713 07525 071692
Specialist Contractors cont...	Ecological Fencing Keystone Habitats The Old Barn Park Farm Buildings Beverston Tetbury Gloucestershire. GL8 8TT	Contact Tel No Mobile No	Joe Bradshaw 01666 503687 07894 066688
	Drain Clearance Lanes Group plc Lancing House Broughton Mill Road Bretton, Flintshire. CH4 0BY	Tel No	01244 661691
	Sheet Piling Sheet Piling (UK) Limited Oakfield House Rough Hey Road, Grimsargh PRESTON. PR2 5AR	Tel No	01772 794141
	Water Utilities Morland Utilities Ltd Unit H8, Halesfield 19 Telford Shropshire. TF7 4QT	Tel No	01952 681981
	Demolition M&J T Davies Hafod Industrial Estate, Johnstown Wrexham. LL14 6HF.	Tel No.	01978 840002
	Plant Hire (Excavators and Dumpers) Bullen Plant Hire Ltd 45 Appley Lane North Appley Bridge Wigan. WN6 9AD.	Tel No	01257 253111



Role	Organisation and Address	Position	Name
	Plant Hire (Crushing and Screening) Clive Hurt Plant Hire Ltd Sandham House Redrose Drive Lancashire Enterprise Business Park Leyland. PR26 6TJ	Tel No	01772 432475

1.4 Structure of Verification Report

This Verification Report is made up of:

- An introductory description of the site and the background to the remediation project (Sections 1 and 2);
- A description of the remediation works and how they were carried out in practice (Section 3);
- Verification details and data confirming the extent of mitigation and the volumes of materials treated and disposed, along with the status of any replaced materials (Section 4).
- A statement of site conditions at the completion of the remediation works, including the identification of any residual risks (Section 5); and
- A record of the consents and permissions that were gained in order to carry out the various remediation actions at the site (Section 6).

Documentary evidence in the form of test results, photographs, site diaries and excavation surveys is provided as a separate volume of Appendices, which also includes records from the ancillary works that were conducted alongside the remediation (the demolition of a disused office building and the installation of new potable water supply pipework).



1.5 Disclaimer

This report is based upon the information available to IKM Consulting Ltd at the time of preparing the report. The information provided to IKM Consulting Ltd by other parties in connection with the preparation of this report is believed to be accurate to the best of IKM's knowledge. IKM shall not be held responsible for the negligence, error or omissions of other consultants. IKM Consulting Ltd does not accept any responsibility for the use of this report by any third party other than those third parties identified in the term deed.



2. SITE CONTEXT

2.1 General

The site within which the remediation has been undertaken is known as Maelor Works, Marchwiel, Wrexham LL13 0UW. The centre of the site has a National Grid Reference SJ38087 48086. The remediation site area comprises the majority of the NGPH landholding at the Maelor Works site, with the NGPH site reference number 138S. The site has been divided into three adjoining areas by NGPH, known as Areas A, B and C. Remediation has only been required within Areas A and C, which together form the majority of the main occupied area at Maelor Works (hereafter referred to as Area AC). No remediation has been required for land within Area B, which is not referred to further in this report. Land boundaries, remediation areas, and surrounding features are shown on Figure 1. Site Location (Drawing A1-13627-3051).

2.2 Site Description

The site is situated in a largely rural setting, albeit that the surrounding area was formerly part of the Royal Ordnance Factory (ROF) Wrexham facility, which consisted of widely scattered manufacturing and small storage facilities in the predominantly open land to the north. The main manufacturing area for the ROF is now occupied by Wrexham Industrial Estate, approximately one kilometre to the north. A few remnant brick built buildings from the ROF lie in the fields immediately to the north of the site.

The shallow River Clywedog river valley lies immediately to the north of the site, with the river some 120m away at its closest point. The river flows west to east past the site. A second smaller watercourse, Bedwell Brook, flows towards the southern boundary of the site from the west; it then passes through a culvert under the former railway line embankment, before entering and flowing in a steep sided valley through the south easternmost corner of the site area.

A number of long established farms are located around the site boundary to the west, south and northeast.



The site is accessed via a private access road that leads north from the B5130 public road and enters Area AC through the main reception gate, shared with other site users. Area AC is completely surrounded by a boundary fence, with a number of secured access points from the surrounding third party agricultural land, including a long established un-surfaced track way that passes the northwest corner of the site and continues along the northern boundary and away to the northeast.

2.3 Site History

The site was originally open farmland that was developed into a small part of the extensive, former ROF Wrexham, the majority of which lay to the north of the site. Following closure of the ROF, Area AC was redeveloped as a large coal and ultimately oil-fuelled town gas manufacturing works. Following closure of the gasworks in the 1970s, Area AC has been used for a variety of gas distribution related activities, with some new office buildings constructed over the footprint of the former gasworks. Other parts of the Main Works site have subsequently been used for the storage of containerised gas (Flogas) and portions of the site have been sold to a separate gas utility company (Wales and West Utilities – WWU). Large parts of the northern and south-eastern sectors of the site have essentially been disused since the closure of the gasworks operations.

Rail connections used to supply the gasworks site via a private track on an elevated embankment crossing Bedwell Brook in the southeast sector of Area AC. The track itself was dismantled sometime after the gasworks closure.

The history of the site is discussed in more detail in previous site Investigation factual reports, including in particular, IKM REP002.

2.4 Geology

According to published mapping, the site is underlain by substantial thicknesses of glacial drift, with bedrock at depths in excess of fifty metres below ground. Bedrock is indicated as sandstone from the Triassic Sherwood Sandstone formation, although the boundary between this rock formation and Carboniferous Coal Measures is postulated as being close by.



The glacial drift deposits in the area are variable in both lateral extent and thickness and range from loose sand and gravel to stiff glacial till. Some more recent freshwater alluvial deposits have developed over the glacial drift along the valleys formed by modern surface water courses. These near surface deposits tend to be rich in clay and of relatively low permeability.

The depth of glacial drift beneath the site is considered sufficient to effectively isolate the bedrock from surface activities and any associated contamination.

2.4.1 Area AC1

To the northeast, the Area AC1 surface is an area of soft standing / loose aggregate with mixed vegetation growing through. Trial pitting and water main installation works in this area found thin made ground, overlying firm brown sandy clay. Made ground deposits were observed from ground level to between 0.3m and 2.1m below ground level (bgl). The made ground consisted of re-worked clay with some demolition waste including bricks and wood.

In the north and west, the surface consists of gravel and loose debris on to a concrete base 0.3m thick with re-bar and clay underneath. Beneath the hard standing is made ground up to 3.2m in depth, which included reworked clay and sand and gravels and is underlain by natural sandy clay with bands of gravel. Low permeability glacial till was proven at between 4.50m and 5.10m below ground.

Immediately to the south, the former gas purifiers were housed in a below ground concrete bunker type structure which remains largely in place, albeit backfilled with made ground consisting of road and pavement excavation arisings and plastic pipe fragments.

The main groundwater abstraction and water treatment area lay to the south of the former purifier bunker structure, in an area also covered by a concrete slab (previously used for the re-vivification of spent oxide). Made ground beneath the slab extended to 2.5mbgl with sandy silty clay beneath.



2.4.2 Area AC2

The majority of Area AC2 is made up of open storage areas covered in a thin layer of loose imported aggregate, with a perimeter road around the western boundary and roadways through the centre and along the eastern boundary.

Excavations revealed an historical made ground deposit beneath the surface cover, comprising a mixed layer of clay, sand and rubble, typically including combustion residues and stained black. There were numerous residual brick and concrete foundation structures within this layer, some of which extended into the underlying natural silty sands and gravels and soft clay (glacial till).

The made ground was variably impacted by free phase black tar, greenish brown, viscous oil and strong hydrocarbon / solvent odours in places.

Visible and odorous contamination indicators were strongly linked to the historical gasworks structures recorded as having been situated in this area, although it was apparent that some sub-surface migration of the contamination had also taken place.

2.4.3 Area AC3

Pond 2 appeared to have been excavated into natural deposits of soft brown clay (glacial till) and made ground was largely absent.

2.4.4 Area AC4

This area was previously used for tipping of waste materials from the site and the area to the north of Bedwell Brook consists of a tipped wedge of made ground, with a steep densely vegetated slope down to Bedwell Brook to the south. To the west of the open brook channel is a large and very steep embankment mainly formed of loose grey ash, which is the former railway embankment, leading into the main site area to the west. The embankment contains many rabbit holes, with much loose ash material scattered around and below the entrances. The southern bank of Bedwell Brook is less steep and tree covered to the agricultural field boundary beyond, some smaller banks of ash material are present towards the western end (separate from the main embankment).



Trial pitting within the tip area to the north of the brook showed the made ground in this area to consist of reworked clay, with waste concrete with re-bar and bricks. Some trial pits recorded waste including bricks and tiles mixed in with clay and solidified coal tar.

The brook channel itself appears to have been excavated into the soft glacial clay that underlies the made ground deposits.

2.4.5 Mining

The site is considered to be unaffected by historical underground mining. One historical photograph from the 1950s, during the construction of the adjacent gasworks, shows a shallow, borrow pit excavation extending over land immediately to the southeast of Bedwell Brook, assumed to have been used as a source of construction materials (sand/clay fill) for the gasworks or railway. The site is not likely to be underlain by any strata that may be targeted by mining or quarrying in the future.

2.5 Hydrogeology

No natural soils are exposed at the site surface, but a shallow groundwater table has been developed within made ground and natural granular strata, perched on an irregular surface of low permeability clay that underlies the entire site area.

Groundwater movement in the shallow alluvial soils is largely controlled by local variations (lateral and vertical) in permeability and recharge and the buried topography of the underlying low permeability clay surface. A shallow groundwater high is apparent in the western central part of Area AC, in the vicinity of the former tar tank (and in the area known to be affected by leaking water mains). Groundwater flow paths are generally to the northwest and north, and to the southeast and south of this point. Most of the flow would be expected to occur within sand / sand and gravel strata that typically lie immediately above the clay.



Granular strata vary in thickness from less than 1m to over 4m across the site area, with many of the coarser gravel deposits being present as metre scale, linear channel features oriented roughly northeast to southwest and incised into the clay surface. Groundwater flowing northwest from the groundwater high is likely to discharge directly into a French Drain that has been installed along the western perimeter of the site, cut into the original ground, below the level of the site and typical groundwater surface levels.

The granular alluvium strata are largely absent in the far north of the site, which is likely to prevent significant groundwater movement beyond the northern boundary; groundwater is sometimes observed seeping onto the ground surface in this area during wet weather.

The sand stratum extends across the majority of the south and eastern site area, except along the north bank of the Bedwell Brook valley feature, where tipped made ground deposits have been placed directly on the glacial till surface. Shallow groundwater is thought to flow through this made ground deposit along the glacial till interface and to discharge to the brook below the foot of the tipped slope; groundwater spring discharges are not generally visible in this area.

A degree of interaction between surface water drainage and the shallow groundwater in the granular alluvium is suspected, but has not been quantified. Surface water drain discharges to the Bedwell Brook are observed to persist even during extended periods of no rainfall.

The bedrock strata at depth beneath the site are known to form designated aquifers (classified by Natural Resources Wales as a Principal Aquifer), but the groundwater is effectively isolated from surface impacts by the intervening cohesive drift deposits.

The site area has been reported as lying within the outer zone (Zone 2) source protection zone of a bedrock water abstraction borehole in Wrexham Industrial Estate approximately 2km to the north of the site. Up to date details on groundwater source protection zones are available on request to Natural Resources Wales (not currently available on-line).



2.6 Hydrology

The site sits on a watershed between the River Clywedog to the north and Bedwell Brook to the southeast (although Bedwell Brook itself flows into the River Clywedog approximately one kilometre to the east of the site). The Clywedog sits in a broad, shallow valley north of the site, with a network of agricultural ditches and field drains draining the land between the site and the river. Bedwell Brook is similarly, but separately fed by ditches and drains in agricultural land to the south of the site. It is a much smaller watercourse than the Clywedog and flows in its own small valley down to the confluence of the two rivers.

Bedwell Brook enters the site area beneath the former railway embankment in the south eastern corner of Area AC and flows in an artificial channel through this part of the site. The northern flank of the channel has been steepened and constrained by tipping activities within the site to the north. The northern bank and base of the channel immediately below and downstream of the surface water drainage outfalls (approximately 20m downstream of the railway embankment culvert exit) has been lined with concrete to prevent erosion into the main tipped deposit (this was only revealed during the works). The concrete channel extends for approximately 20m further downstream, with the remainder of the channel to the access road culvert being almost straight and cut into natural clay deposits.

The majority of the site area is largely flat and level and does not contain any open, flowing water courses. An extensive surface water drainage system has been installed across Areas AC2 and AC3, presumably at the time of the original construction of the gasworks site. The majority of this Area AC (excluding Area AC1 in the far west and north western corner), along with the north eastern WWU site area, drains into three main branches, all of which ultimately discharge to the Bedwell Brook in the southeast of the site. The current status of this drainage system has been investigated as part of the remediation works, with the links between the operational site areas and Bedwell Brook confirmed. A separate branch of the surface water drainage serves the Flogas compound in the south of the site and discharges into Pond 2 (Area AC3), which in turn overflows intermittently to Bedwell Brook upstream of the railway embankment.

Details of the drainage system are included in the individual remediation plans for the site areas (see Sections 3.1, 3.3 and 3.5.3).



The western and north western part of Area AC (including Area AC1) is thought to be serviced by an informal drainage system that leads to the external network of field drains and ditches to the north of the site. A coarse aggregate interceptor (French Drain) installed along the western boundary of this part of the site is also connected into this drainage network at the north western corner of the site. Direct drain discharges to the French Drain have not been identified and it is thought that only perched groundwater from the adjacent raised made ground is intercepted by this feature. No further investigative or remedial work was carried on these drainage features during this remediation project.

2.7 Summary of Site Investigations

The site and surroundings have been subject to a number of site investigations and risk assessments that have fed into the formulation of the current remediation project. A listing of available site investigation reports, with a brief summary of their contents is provided in Table 2 below.



Table 2: Previous Report Summaries

Title	Author / Date	Content
Final Environmental Assessment - Factual Report of Maelor Works, Wrexham Clwyd	Komex Clarke Bond, February 1996	Site wide intrusive investigations to determine sub-surface conditions and the distribution of potential contamination sources. Hydrocarbon impacted soils were identified in the west, southwest and southeast quadrants of Area AC (former tar processing and site tipping areas). An area of shallow spent oxide deposits was identified in the northern quadrant of Area AC. Potential residual radioactive contamination from former use of uranium catalyst also identified (incomplete remediation previously attempted by others not fully documented). Tar tank and liquor well identified as potential source of residual free product (tar) and tarry water.
Post Remediation Report for Radiological Survey and Remedial Works at Maelor Works, Marchwiel, Wrexham and EM Edwards Works, Llandarcy Neath.	Komex Clarke Bond, December 1998	Description of actions taken to deal with radioactive contamination associated with residual uranium catalyst materials left at the site after decommissioning of the oil gas plant and subsequent partial site clearance. Used as the basis for specifying additional confirmatory site surveying from radioactive contamination during Stage 1 site investigations and monitoring support during subsequent (non-radioactive) remediation works (additional surveying and recommendations for remediation monitoring incorporated into IKM Risk Assessment and Remediation Design Report, 2014 – see below).
Factual Additional Site Investigation at Maelor Works, Wrexham	Komex Clarke Bond, November 1999	Follow-on investigation of potential contaminant sources identified in 1996 investigation, with a focus on possible off-site migration of contaminated waters. Establishment of monitoring locations for use in the production of the 2000 hydrological/hydrogeological report (see below).
Hydrological and Hydrogeological Investigation at Maelor Works, Wrexham	Komex Clarke Bond, 2000	Water level monitoring and quality testing to establish the hydrological and hydrogeological conditions within the main site boundary (Area AC). Used to estimate groundwater flow directions and identify drainage catchments and watersheds within and around the site. Establishes a baseline for groundwater quality in different parts of the site area.



Title	Author / Date	Content
Factual Post Remediation Report for the Former Gasworks Maelor Wrexham.	Komex Europe, February 2001	Details of remediation works conducted following initial site assessments. Removal of accessible significant contamination in the form of main tar tank contents (previously backfilled with rubble/misc. materials) and shallow spent oxide deposits in northern Area AC. Free phase product in made ground / granular alluvium to south and west of tar tank and in drainage / Bedwell Brook / Pond 2 sediments not targeted at this stage.
Factual Site Report - Area A - Former Gas Works - Maelor Works - Wrexham	Worley Parsons Komex, August 2006	Factual extract report for a small part of Area A (northwest corner of Area AC), to the north of the former gas purifier bunker.
Environmental Assessment Site Investigation Report - Maelor Works, Wrexham	Worley Parsons, January 2012	Supplementary site investigation report aimed at providing information for further risk assessment of the site (human health and controlled water receptors), updated from historical investigations and partial remediation work. Acts as the basis for identification of additional remediation requirements, supplemented in turn by the Stage 1 site investigations as reported by IKM (see below).
Areas A and C Stage 1 Risk Mitigation Site Investigations Factual Report	IKM 2014	Additional targeted investigation of parts of Area AC where remediation actions were deemed likely to be justified on the basis of available historical information. Collated factual information that informed the production of the remediation design for the main site area (when combined with previous reports described above).
Area B East Stage 1 Risk Mitigation Site Investigations Factual Report	IKM 2014	Desk study and intrusive site investigation report for an area of NGPH owned agricultural land to the southeast of the main site. Currently leased out to third parties as informal grazing land for horses. Used as the basis for discounting the requirement for any remediation under the current land use scenario.



Title	Author / Date	Content
Area B West Stage 1 Risk Mitigation Site Investigations Factual Report	IKM 2014	Desk study and intrusive site investigation report for an area of NGPH owned land (former railway cutting) to the west of the main site. Currently leased out to third parties as unmanaged woodland and informal foraging land for chickens. Used as the basis for discounting the requirement for any remediation under the current land use scenario.
Risk Assessment and Remediation Design Report	IKM 2014	Risk assessment of the different site areas within the current NGPH landholding to determine the requirement for remediation and ongoing management of the site. Based on information collated from all previous site investigations. Using the risk assessment outcomes to determine the requirement for remediation and providing a description of the preferred remediation approach and methodologies. Acts as the main basis for the planning application for the works.
Garage Investigation Report	IKM 2014	Supplementary investigation of conditions beneath the floorslab of the modern garage building adjacent to the proposed main soils remediation area in Area AC. Demonstrated the absence of significant contamination beneath the building and precluded any requirement to demolish the garage as part of the remediation (subject to confirmatory inspection and assessment during remediation excavations).



Details of the site investigation data and risk assessments used to determine remediation requirements are contained within IKM REP005.

The key issues identified by the site investigations were:

- The presence of significant volumes of free phase tar / liquid hydrocarbons in made ground and natural strata within the former by-products storage and production areas within the western sector of the site (known as Area AC2);
- The presence of impacted shallow groundwater within Area AC2 and a further plume of dissolved phase contaminated groundwater extending in the direction of groundwater flow towards the northwest corner of the site (known as Area AC1);
- The presence of tar / oil contaminated sediments within surface water drains and the surface water bodies into which the drains discharge (Bedwell Brook and a small artificial pond remotely connected to Bedwell Brook (known as Pond 2)).

The site investigations also confirmed that previous phases of remediation work had successfully removed the contents of the main bulk tar tank in Area AC2, and all significant deposits of spent oxide materials from the surface / near sub-surface of the site. Bulk excavation and removal of impacted made ground had also been undertaken from a rectangular area of ground (land currently owned by WWU) separating Area AC1 and Area AC2 in the western site sector. These remediation actions have previously been reported / verified to NGPH separately by other parties.



3. REMEDIATION WORKS

The remediation design for the site has been prepared in order to systematically address identified unacceptable risks in such a way as to allow the continued use of the site as a mixed commercial office/workshop/distribution and open storage facility. The design was implemented in accordance with the methodologies submitted as part of the works planning application and in applications for associated permits and consents required by the regulators.

A comprehensive programme, showing the sequence of actions required for enabling works and the remediation and associated engineering works, was prepared in advance and updated to reflect delays and changes in sequence arising during the course of the works. Updated versions of the programme were provided to NGPH and the project team as part of the regular contractor progress reporting throughout the works.

A copy of the final version of the Microsoft Project programme is provided as Appendix B.

This section of the report includes a summary of the Conceptual Site Model (CSM) and targeted pollutant linkages, upon which the remediation design was based, followed by a statement of the over-arching objectives and remediation strategy adopted (Sections 3.2 and 3.3). The remainder of Section 3 contains a detailed description of the various remediation tasks completed (including Enabling Works (Section 3.4), the demolition of a derelict office building and the installation of new water supply pipework (Section 3.9)), with a separate discussion of residual contamination issues and reinstatement works (because of the integrated nature of the remediation works, much of this is a re-statement of the remediation works description in the other sub-sections). Detailed discussion of verification / validation requirements is deferred to Section 4.

3.1 Site Conceptual Model and Pollutant Linkages

The CSM, based on the site assessments described above, contains pollutant linkages that require some form of mitigation / remediation in order to allow continuation of existing site occupation/uses. The linkages are described in Table 3 below.



Table 3: Pre-Remediation CSM Linkage Table

Site Area	Source	Pathway	Receptor	Current site conditions		
				Consequence	Likelihood	Risk
AC1 AC2	Variable made ground impacted by gasworks process residues and asbestos fibres, exposed at the site surface or present at shallow depth with no containment or controls in place.	Direct contact and dust / vapour inhalation.	Site users and trespassers.	Moderate / severe – exceedance of preliminary CLEA derived assessment criteria, inhalation of excess asbestos fibres (above background) and presence of free phase tar, and spent oxide.	Unlikely – no capping layer or other containment, but limited contact under normal site use scenarios.	Unacceptable under current site conditions / use, due to uncontrolled nature and potential severity of consequence.
AC1 AC2	Free phase tar and contaminated made ground and granular alluvium extending into the saturated zone with no control over infiltration.	Migration / leaching by infiltration and shallow groundwater, followed by groundwater migration and movement through site drainage.	Third party field drains / ditches (linked to River Clywedog. Bedwell Brook	Moderate / severe – visible entry of free phase hydrocarbons / exceedance of surface water quality criteria.	Likely – typical contaminants detected in water samples, and free phase contamination of sediment found in Bedwell Brook, no containment or pathway interruption in place.	Unacceptable under current site conditions / use



Site Area	Source	Pathway	Receptor	Current site conditions		
				Consequence	Likelihood	Risk
AC1 AC4	Contaminated shallow groundwater in made ground and granular alluvium.	Migration along local hydraulic gradients / entry into surface water drainage.	Third party field drains / ditches (linked to River Clywedog. Bedwell Brook.	Moderate / severe – concentrations in Bedwell Brook and field drains exceed surface water quality criteria, but no detectable impact on River Clywedog.	Likely – but limited volumes suspected.	High, remedial actions necessary under current conditions / use.
AC1 AC2	Free phase tar and tar contaminated made ground exposed at the site surface or present at shallow depth with no containment or controls in place.	Inhalation of vapour.	Site users / trespassers.	Moderate –sporadic exceedance of site specific model derived assessment criteria.	Likely – no capping layer, contaminants present in shallow deposits.	Moderate, risks reduced through other remediation actions.
AC2 AC4	Contaminated sediments collected in surface water drainage pipework and around outfalls.	Flushing by infiltration and shallow groundwater, followed by discharge to surface water bodies.	Area AC3 pond / Bedwell Brook.	Moderate / severe – visible hydrocarbons in surface water sediments and standing water adjacent to outfalls, but no detectable rise in water concentrations under typical conditions.	Likely – limited volumes and intermittent, depending on rainfall.	High, remedial actions required due to uncontrolled nature of discharges.



Site Area	Source	Pathway	Receptor	Current site conditions		
				Consequence	Likelihood	Risk
AC1 AC2	Shallow groundwater within granular alluvium impacted by dissolved gasworks process contaminants.	Lateral migration along hydraulic gradient towards surface water.	River Clywedog.	Mild – no detectable rise in water concentrations under typical conditions.	Unlikely – due to limited volumes, absence of direct pathway.	Low. No remedial actions required under current conditions / use.



The source, pathway and receptor descriptions and associated pollutant linkages in the above table are described in detail in IKM REP005 and are illustrated on the CSM plan, Figure 2. Conceptual Site Model Plan (Drawing No. A1-13627-3050).

3.2 Remediation Objectives and Criteria

Principal objectives for the remediation were:

- i. Removal of significant free phase tar and other mobile hydrocarbon contamination present within made ground deposits and natural strata and residual structures / pipework beneath the site surface;
- ii. Removal and treatment of contaminated made ground from site surface / near surface deposits posing an unacceptable risk to site occupants and users and replacement with verified suitable materials;
- iii. Removal, treatment and disposal of significantly contaminated, perched groundwater from beneath the site and overall improvement in water quality discharging from the site to surface water drains adjacent to the site boundary;
- iv. Treatment of grossly contaminated, excavated made ground deposits and natural strata to prevent ongoing leaching of contamination to perched groundwater and site surface water drainage. Treated material to be rendered suitable for re-use as sub-surface fill across the site area;
- v. Removal and treatment of sediments from delineated sections of the site surface water drainage pipework and impacted receiving surface water course / pond.

In addition, the works were to include:

- vi. Safe demolition of the redundant and derelict former North East Wales District Office (NEWDO) building. Demolition materials to be made available for on-site reuse or off-site recycling, with separate disposal of asbestos containing materials to a suitable off-site facility;



- vii. Provision of a new potable water supply connection for the occupied site buildings, including the isolation and disconnection / replacement of existing pipework that is leaking. Provision of suitable protection to the newly installed pipework to prevent any potential ingress of contamination from surrounding ground.

3.3 Remediation Strategy Overview

The agreed remediation objectives were to be achieved through the implementation of a comprehensive remediation strategy that is summarised in Table 4 below.

Table 4: Remediation Strategy Summary

CSM Source Area	Details of Target Contamination/Linkage	Proposed Remediation Strategy*
Area AC2	Soils and made ground impacted by free phase tar and other gasworks residues along with associated contaminated groundwater within the made ground and granular alluvium beneath the former gas and tar chemical processing area. Current direct contact/ ingestion risks to site users, exacerbated by potential future disturbance or surface erosion/run-off). Ongoing risk of further release of free phase and leachable contamination into the surrounding soils and groundwater.	Dewatering and selective excavation and sorting of visibly contaminated materials from Area AC2; Treatment by screening and ex-situ solidification / stabilisation to render the contamination non-leachable and immobile under foreseeable site use conditions; Replacement of treated materials below the site surface and beneath cover materials (recovered from excavated made ground); Pre-treatment of recovered groundwater and discharge to offsite treatment plant (local WWTW).



CSM Source Area	Details of Target Contamination/Linkage	Proposed Remediation Strategy*
Area AC2	Asbestos Containing Materials and contaminated made ground. Discrete fragments and disseminated fibres. Current risk to site users due to inhalation of fibres, exacerbated by future disturbance or erosion/ run-off.	Segregation and removal of visible individual fragments of asbestos containing materials during excavation and demolition. Treatment of materials potentially contaminated by disseminated fibres by stabilisation/ solidification preventing future release of fibres under foreseeable site use conditions. Provision of durable cover (with no quantifiable asbestos fibres) in all areas where contaminated made ground has been excavated/replaced, protecting stabilised materials and preventing generation of dust through weathering.
Area AC1	Dissolved phase contaminated groundwater within the made ground and granular alluvium (Area AC1). Presents a risk to adjacent surface water receptors (private agricultural field drains and ditches) due to sub-surface migration and site drainage discharge.	Abstraction of groundwater from the most contaminated part of the plume, with ex-situ treatment and discharged to local foul sewer for off-site treatment (local WWTW). Removal and treatment of the principal source of the contamination (Area AC2 free phase tar and contaminated made ground), thereby preventing future release of dissolved phase contamination from up-hydraulic gradient of Area AC1.
Area AC2, AC3, AC4	Tar and free phase hydrocarbon impacted surface water and drain sediments. Current and ongoing risk of further release of free phase contamination into the receiving watercourses. Current direct contact, ingestion and vapour inhalation risks to site users.	Excavation and removal of contaminated sediments from open water channel / pond and jetting / clearance of surface water drains between the original source areas and the receiving watercourse. Dewatering and incorporation of the contaminated sediments into the ex-situ treatment process (stabilisation / solidification). Transfer of recovered contaminated water to the site water treatment facility for treatment and discharge to foul sewer.

*Details of designated remediation areas are shown in Figure 3. Remediation Area Locations (Drawing No: A1-14890-3005).



3.4 Enabling Works

In order for the remediation works to be successfully completed, the following enabling works were required:

3.4.1 Site Set-Up

IHB established a segregated site compound and ex-situ treatment area for the duration of the works. Individual remediation areas were also fenced off with temporary Herras type panels to prevent any unauthorised / accidental access into the active remediation areas by other site users (normal site tenant operations and activities continued throughout the remediation works period).

The compound facilities included (all hired in units):

- Electrical generator (supplying to all contractor units on-site);
- Site Office (for IHB supervisors);
- Site Canteen (for all site staff);
- Engineers office (for IHB/IKM supervisory support staff);
- Meeting room (for site visitors);
- Toilet;
- Decontamination Unit (in ex-situ treatment compound – all entry / exit to working remediation areas were via the Decon unit);
- Fuel Bowser for supplying remediation plant;
- Diesel tank for temporary storage of fuel for site plant;
- Storage containers (x2) for storage of miscellaneous site equipment and PPE;
- Waste storage, segregated containers for general waste (in site compound) and contaminated materials / equipment (in ex-situ treatment compound).



IHB also undertook extensive relocation of tenant owned materials from the open storage areas that lay within active remediation zones (and replacement of these materials on completion of the works).

3.4.2 Water Treatment Facility

A temporary water treatment facility (WTF) was established on the site, in order to treat all groundwater arisings (excavation dewatering and groundwater abstraction) and any rainfall or surface water run-off collecting within excavation areas, prior to discharge to the local foul sewer. The sewer discharge was subject to a discharge consent from the local waste water utility company (Dwr Cymru). The WTF was an integral part of the groundwater remediation works and further details of the WTF operation are provided in Section 3.5.1 (which also describes the installation of new groundwater abstraction wells at the commencement of site works).

3.4.3 Physical Exclusion of Protected Species

Historical ecological surveys had established the requirement for the physical exclusion of protected species (principally Great Crested Newts), from all active works areas within potentially suitable habitat (Pond 2 / Bedwell Brook surrounds and the new water main northern corridor). This was achieved through the installation of extensive bespoke “newt fences” (and regularly spaced live traps) around the entire perimeter of the specified working areas and an extended programme of monitoring and trapping to capture and relocate any such animals within the excluded areas.

All sediment removal works within the surface water bodies being remediated was also carried out under the supervision of a qualified ecologist who directed the rescue and relocation of any animals caught up in the dewatering and excavation works. All this work was conducted in line with the agreed ecological management methodology / plan and the terms of the European Protected Species Licence issued by Natural Resources Wales (see Section 6 and Appendix C for details).



Additional surveying of works areas for nesting birds and the placement of bird deterrent tape in areas declared free of bird nests, was carried out in the lead up to any work activity in potentially sensitive areas. Removal of vegetation along the corridor for the new potable water supply pipeline and within the immediate vicinity of Bedwell Brook / Pond 2 sediment removal works, was carried out as soon as possible after these areas had been declared free of nesting birds.

All vegetation removal was undertaken under supervision by a qualified ecologist to prevent any disturbance to nesting birds (in adjacent areas or nests only discovered during the works) or other avoidable habitat damage.

3.4.4 Sheet Piling

Provision of sheet piled support to the edge of deep excavation areas (>2m deep), in AC2, adjacent to existing site buildings and third party property boundaries around the Area AC2 excavation.

Sheet piling was undertaken by a specialist contractor (see Table 1), with recoverable, interlocking steel piles being hydraulically driven to depths of around eight metres below the ground surface, well into low permeability clay strata beneath impacted made ground and granular alluvium. Piling depths were reduced towards the south, where excavation depths were less (<2m) and no piles were required for the southernmost excavation areas (to the south of the retained garage building). All piles were successfully removed / recovered on completion of the backfill operations in the adjacent areas. The extent of the sheet piling is shown on Figure 5 (see Section 3.5.2 for details).

3.4.5 Bedwell Brook Channel Survey

The existing Bedwell Brook channel was surveyed by IHB site staff and the data was used to prepare drawings of existing and proposed profiles for the Ordinary Watercourse Consent (OWC) application that was submitted in advance of the sediment removal works. The OWC was subsequently issued by WCBC and a copy is included in Appendix C.



3.4.6 Miscellaneous Works

Additional activities undertaken in support of the remediation were:

Recording of pre-start site conditions (see Appendix A – Pre-start Survey Photographs).

Demolition and clearance of material storage bays and a disused gas fire-fighting area (a small blockwork wall, with a loose slab floor and associated gas supply pipework), the only above ground structures located within the main excavation area (materials were added to the main concrete stockpile).

Disconnection of services from the derelict office building prior to its demolition (dealt with as part of regular dialogue with the demolition contractor and site tenants in the surrounding buildings).

3.5 Remediation Implementation and Practicalities

The remediation methodologies to be used for each site area / remediation action were developed as part of the remediation design (IKM REP005). The methodologies and practical implementation details for each remediation area are described in detail in the following sections. The site remediation area designations (AC1, AC2, AC3 and AC4) are shown on Figure 3.

3.5.1 Area AC1

The remediation approach specified for this area involved the abstraction of recoverable impacted groundwater from shallow made ground and granular alluvium, followed by pre-treatment and discharge to the local foul sewer (for treatment off-site by the water utility company). The work was carried out by the specialist sub-contractor, Geo². The pre-treatment of the abstracted groundwater was carried out by the temporary WTF installed at the site by Geo², this facility was also used to treat groundwater and surface water run-off originating in the Area AC2 excavations.



Based on the results of the test pumping from peripheral boreholes, four new large diameter (200mm), groundwater abstraction wells were sunk in the southern sector of Area AC1 in the centre of the anticipated plume originating from Area AC2 to the south. The locations of the new wells and existing monitoring wells are shown in Figure 4. Area AC1 Remediation Plan (Drawing No. A1-14890-3003).

Details of the new well construction and the design of the extraction system are provided in the Geo² reports contained in Appendix L. The abstraction wells were finished flush with the local ground surface and provided with a bolted cover plate to protect against ingress of soil or other debris.

The zone of influence for the abstraction wells was determined through measurement of rest water levels at adjacent existing monitoring wells as pumping commenced. This monitoring was continued throughout the groundwater abstraction period. Volumes of water abstracted from each well were controlled through the use of a flow regulator on each well head, which were adjusted to maintain a steady drawdown within the well without causing it to dry out.

In practice, the total volume of groundwater abstracted was limited by the absence of a groundwater abstraction licence for the works (the application submitted in advance of the remediation starting was not ultimately determined by NRW before the end of site works). This limited total abstraction at the site to some 20m³ per day.

Groundwater abstraction wells began pumping from 26th March 2015 and were maintained and operated by Geo² for the period of the active remediation works on-site (up to 17th June 2015). All abstracted groundwater was pumped directly to the site water treatment facility for treatment via a dedicated treatment line (settlement and activated carbon filtering). All treated water was then directed to the designated foul sewer manhole (agreed with Dwr Cymru – as shown on Figure 4), before being treated at the local waste water treatment works (WWTW) (also operated by Dwr Cymru in this case).



The total volume of water leaving the treatment facility was recorded daily by IHB onsite personnel and flow rates from each of the abstraction wells was measured on a regular basis, with the split between excavation dewatering and groundwater abstraction volumes then being estimated by difference.

3.5.2 Area AC2

The remediation methodologies specified for this area involved the selective excavation (and segregation) of impacted made ground and granular alluvium beneath identified sectors of the former operational area of the gasworks, followed by ex-situ treatment by solidification / stabilisation reagents and backfill of the excavation using treated (and segregated) materials. Excavations were kept free of standing water (including inflowing groundwater and free phase hydrocarbons) by pumping to the on-site water treatment facility. Segregated oversize materials were crushed and re-used separately.

All works in this area were carried out under the direction of IHB, using hired in excavation plant (Bullen Plant Hire Limited) and a combination of in-house operatives and operatives provided by the plant hire company.

The treatment process was conducted in a separate, secure area of the site and is described in more detail in Section 3.5.4. The excavation areas had been identified using data from the site investigations / risk assessments and were marked up on working site plans for day to day reference. The excavation areas were divided into 10 by 10 metre grid squares, with each square being given an alpha-numeric identity to allow easy and consistent reference for all materials arising from the excavations. The grid was surveyed in using the installed northern sheet pile walls as the reference boundary (see Figure 5. Area AC2 Remediation Plan (Drawing No: A1-14890-3004).



3.5.2.1 Concrete and Loose Aggregate Surfaces

The majority of Area AC2 was covered in imported loose clayey, sandy gravel (aggregate assumed derived from quarry scalplings) that was a pale grey colour and visibly differentiable from underlying historical site surfaces (dark grey / black made ground composed of mixed rubbly clay). No contamination had been previously identified or was suspected in these materials.

The loose aggregate surfacing was scraped back in layers by an excavator and placed in temporary stockpiles on parts of the site awaiting excavation / over the retained former tar tank / other areas already backfilled. This recovered aggregate was designated as suitable for later reuse without treatment (subject to visual inspection and testing).

Concrete surface slabs and buried foundations in a wide variety of forms (reinforced foundation slabs, strip footings, ring beams) were broken out using hydraulic hammer attachments on the excavation plant. A large concentration of reinforced concrete slabs and foundation structures was found in the area immediately to the west of the existing garage building, extending down to depths approaching 1.5m in places and resulting in a significant increase in the volume of concrete break out over that anticipated in the remediation design.

Broken out concrete was transported by dump truck to a designated stockpile in the ex-situ treatment area to await crushing. Metal reinforcement was removed as best as practicable during the break out operations, but an estimated 50% remained in the stockpile (further metal recovery occurred during subsequent concrete crushing).

The loose aggregate and broken out concrete was visually/olfactory inspected during excavation and again while being stored within temporary stockpiles to confirm the absence of potentially contaminative materials (including asbestos, tar and oil).



Stockpiled concrete was screened and crushed using a hired in machine from Clive Hurt Plant Hire Limited. The crusher was operating under a mobile plant licence issued by South Ribble Council, a copy of the relocation form covering the work is provided in Appendix C. The crushed concrete (crushed to a 6F2 grading) and recovered original surface aggregate material was used as preferential drainage layers within the post treatment backfill area and as a surface cover to the excavation area on completion of the remediation works.

3.5.2.2 Tars and Other Hydrocarbon Impacted Soils and Structures

The full depth (0.5-1.5m) of made ground in Area AC2, to the west and south of the Training Centre and Garage buildings (see Figure 5), had been identified as variably impacted by visible free tar, other liquid hydrocarbons (oils) and elevated concentrations of typical gasworks contaminants (including cyanide, petroleum hydrocarbons, PAHs and asbestos).

Once surface materials and structures had been removed from the designated excavation area, the underlying made ground was excavated in layers by hydraulic excavation plant, with continual visual assessment being made as to the likely contamination levels present. Due to the small scale variability of the made ground material, it was not generally possible to segregate material that was visibly free of contamination indicators and all excavated made ground material was designated for treatment (after screening out the oversize fraction).

Excavations extended as far as (see Figure 13. AC2 Excavation Grid Squares and Sample Locations (Drawing No A1-14890-3002) for boundary and Grid Square details):

- The pre-installed sheet pile walls to the north and east of the works area;



- The old tank bund and concrete surface slabs in the northwest sector (Grid Squares A1, B1 and C1), where there was an absence of significant thickness of made ground and no visible indications of contamination in immediately underlying natural strata;
- The perimeter roadway and associated buried services that runs around the southern and south western boundary of the designated excavation area Grid Squares D1, E1, F1, G1, and H1 to H7);
- The exposed walls of the former main tar tank (previously emptied and backfilled by others) that remained in-situ, separating the northern excavation area into two parts (a tar/oil contaminated loose brick rubble layer that was laid against the tank walls was removed from the three sides exposed during the excavation (north, west and south walls). Grid Squares B2 to B3.

Contamination typically persisted (as dense non-aqueous phase liquids – DNAPL, black staining and strong coal tar odours) into underlying granular alluvial strata (sand and gravel) and had spread beyond the immediate vicinity of the likely original sources (tar tanks, tar separators / condensers, liquor tanks and the CWG and Benzol plants).

No significant free phase tar contamination was encountered in natural materials to the north of the main tar tank (Grid Squares A1 to A3), although black streaking and a tarry odour was observed in sands and gravels in Grid Square A3. Excavation continued to a layer of mid-brown very sandy coarse gravel that was free of all contamination indicators.

To the west, in Grid Squares A1 and A2, hydrocarbon odours (described as solvent/white spirit rather than tarry or fuel odours) were detected in natural silts, sands and gravels, but there were no visible contamination indicators.



Sandy, clayey silt from this area was segregated from visibly contaminated materials and placed in a separate temporary stockpile (nominated as “Clean 2” for tracking and testing purposes).

An unexpected Light Non-Aqueous Phase Liquid (LNAPL), in the form of a dark green, slightly viscous oil, was revealed by the excavations, associated with the loose rubble layers against the tar tank wall (Grid Squares B2 and B3) and this material was also found in a single gravel channel extending north from the northern tar tank wall. Excavations were therefore extended into this channel and followed the channel alignment to the northeast, to within approximately 3m of the northern sheet pile wall (Grid Square A2).

To the south of the former main tar tank, numerous previously unidentified / delineated concrete and brick structures were revealed, principally constructed against the tar tank west and south walls and in the southernmost sector of the excavation area (Grid Squares H2 to H7). A separate large concrete slab was also revealed at depth (within basal clay) in Grid Square F2. The majority of standing structures were broken out using the hydraulic hammer attachment, but some massive slab structures that were visibly free from any underlying tar contamination were left in-situ. All structures left in-situ were separately surveyed and recorded on the excavation plan (Figure 13). Broken out concrete was removed to the concrete stockpile in the ex-situ treatment area to await further processing.

Made ground materials to the south of the former main tar tank (Grid Squares C2 to H6) also proved to be variably impacted by tar, black staining and tarry odours to the extent that segregation of potentially reusable materials was not practicable. All excavated made ground material from this area was therefore placed in temporary stockpiles and designated for treatment (after screening or riddling to remove oversize material).



The boundary between made ground and natural strata in the excavation areas to the south of the former main tar tank was not always clearly visually definable; this was due to the reworking of material around structures and disturbance caused during previous site redevelopments / demolition / clearance. Generally, made ground rested directly onto thin mid-brown, sandy very coarse gravel that was water saturated.

This typically contained free phase DNAPL in the form of a fluid black tar, concentrated in the base of metre to decimetre scale channels incised into underlying soft, plastic clay. Due to the thin and intercalated nature of the gravel channels, it proved impossible to segregate visibly clean materials from that which contained free phase tar or heavy black staining and tarry odour. All excavation areas were therefore extended to a clay base that was visibly free from free phase tar or other contamination indicators.

The mixed gravel and clay spoil was all transferred directly to the ex-situ treatment area for treatment without any screening / riddling (not practicable due to clay content).

In Grid Squares C1, D1, C2 and D2, made ground was underlain by loose orange brown and grey silty coarse sand, underlain in turn by sandy gravel, all of which was free from visible or odorous contamination indicators. Gravel channels were still present and occasionally took on a grey or black colouration at the interface with the clay, but without any sign of hydrocarbon sheen or odour to indicate the presence of gasworks contamination. These materials were therefore left in-situ.

Within the southern sector of the excavation area (Grid Squares E1 to H6) there were clear visual and odorous indications that the free phase tar had migrated through water saturated, coarse grained natural strata, within gravel channels mainly aligned southwest – northeast across the base of the excavation area.



No sub-surface original source zones were revealed by the excavations, leading to the assumption that the tar originated from above ground storage tanks / pipelines and had entered the sub-surface due to leaks or spills. Volumes of tar in individual channels were typically relatively small (i.e. insignificant) and only amounted to a significant quantity when combined over the whole excavation area. Small amounts of tar impacted gravel were, therefore, left in-situ at the boundary of the excavation areas where further immediate excavation was prevented by services / retained major structures.

Occasional large diameter steel pipes were encountered, typically associated with sub-surface concrete structures; all proved empty and did not appear to be a major historical source of tar contamination. One large diameter (estimated 250mm) clay drain was encountered running at considerable depth (2.5m – 3.0m below original ground level), south to north through the excavation area, this drain was full of water and did not appear to run free.

Sections of the drain to the south of Grid Square C2 also contained significant free tar and associated heavy oily sheen on the water. An interconnection between this drain and higher level, road / surface water drains running west – east along the perimeter roadway was revealed in Grid Square H2. The destination / discharge point of the drain is not known.

All excavated materials were continually assessed by excavation supervisors to determine the need for screening or use of a riddle bucket to remove oversize material at the point of excavation. In some cases, separate temporary stockpiles of oversize and fine materials were formed, awaiting transfer to the ex-situ treatment area (under verbal instruction from the site supervisors). Some additional screening / riddling was conducted on stockpiled materials during subsequent transfer, as deemed necessary by supervising staff.



Therefore, all excavated materials went either direct to treatment (all loose granular material), or formed designated stockpiles (oversize masonry and broken out concrete), managed through close verbal communication between the plant operatives and the site manager/supervisor. Excavations were quantified through surveying on a daily basis and receiving stockpiles and treatment pads in the ex-situ treatment area were checked visually to ensure that the initial segregation (of recoverable material and material requiring treatment) was maintained at all time. There was no need for quarantine stockpiling or the offsite disposal of any material.

3.5.2.3 Impacted Groundwater (Area AC2)

Groundwater within the excavation area was observed to be restricted generally to the granular alluvium, and was perched above the persistent soft, plastic, clay basal layer. Additional perched water was contained within, or above, some of the concrete structures encountered in the made ground, most of this water appeared stagnant and not subject to significant flow. The thickness and persistence of the low permeability clay at depth appeared to have prevent any impacted groundwater from moving vertically into deeper strata beneath or adjacent to the site.

During the excavation works temporary sumps and drain trenches were dug within the basal clay to allow the collection of water/tar released by exposure and excavation of the made ground and granular alluvium. A large capacity, self-priming surface pump removed the water from the temporary sumps and pumped this water directly to the on-site WTF within Area AC1 (see Figure 4) for settlement, free phase oil separation and filtration through sand and activated carbon filters. Dewatering sumps were dug into the basal clay, on an as required basis to maintain the main excavation in dry conditions throughout.



All groundwater and any rainfall ingress to the Area AC2 excavation was pumped directly to the WTF. Minor volumes of water remained in sumps / excavation low points due to time elapsing between removal of the pump and commencement of backfilling. This time was kept to a minimum practicable throughout the works.

3.5.2.4 Radiation Screening

As a result of historical usage of radioactive uranium / nickel catalyst pellets at the site (during a phase of gas manufacture from heavy fuel oil feedstocks), radioactive catalyst pellets and associated soil contamination had previously been found in a number of delineated areas across the Maelor Works site, including a former fire pit area within Area AC2.

All previously identified radioactive contamination had been removed from the site, but in recognition of the potential for exposure of additional contamination during bulk excavations, all excavated materials were inspected and screened for radioactivity by a dedicated, specialist contractor (Aurora Health Physics Limited), working under the supervision of a certified radiation advisor.

Despite the comprehensive and extensive screening and inspection work, no significant radioactive contamination was found during the works and no specific remediation or change to working procedures was required as a result. A copy of the Aurora report on their radiation screening activities for the project is provided as Appendix D.

3.5.2.5 Backfilling

Treated excavated materials and screened and crushed untreated materials were all used to backfill the excavation areas, so as to achieve an even and level surface as close as possible to the original elevation and matched up to the surrounding surfaces / roadways.



Treated materials were placed and spread in layers typically 300mm to 600mm thick and levelled by tracked excavation plant, prior to compaction using a vibrating roller. Subsequent layers of additional backfill, permeable granular fill layers or final cover were added in a similar manner. Recovered granular material (demonstrated as not requiring treatment as per Sections 4.1.2 and 4.2.3), was placed in typically 300mm thick layers within the backfill to provide a preferential pathway for groundwater flow through the backfilled area at depth. One or two granular layers were placed in each backfill area, depending on the depth of the excavation. Sub-surface granular layers were deemed unnecessary where backfill was less than 1.5m in thickness (given that the final surface cover layer was itself granular in nature). Further details are provided in Section 3.11 (Reinstatement and Compaction) and Section 4.6 (Backfill of Excavations).

3.5.3 Areas AC3 & AC4

3.5.3.1 Surface Water Drainage

Surface water run-off from across the site is collected in a series of open grating gully pots, linked by sub-surface solid clay pipework and discharged (without further attenuation or treatment) at two locations: one on the north bank of Bedwell Brook, and the other at the eastern end of Pond 2.

As far as is known, there are no other active surface water drains or discharges elsewhere on site. The surface water drainage network is shown on Figure 6. Service Location Plan Area AC (Drawing No: A1-13627-3048).

The drains connected to the two separate discharge locations are not believed to be interlinked, and are therefore considered as two separate drainage systems, one serving the main Area AC2 operational area (car parks, offices, and garage) and the other the Flogas storage compound and WWU workshops in the south of the site (Area AC3).



Impacted drains (as identified by the Remediation Design Report) were cleared using high pressure water jetting by a specialist contractor (Lanes Group plc – 26-27th May 2015), along with physical clearance of a large blockage within the manhole on the roadway at the site Main Access Gate. Jetting water was retrieved by vacuum suction back into the contractor's vehicle and transferred to the site WTF for treatment and subsequent discharge to sewer.

Drain discharges were fitted with straw bale filters and oil absorbent pads / booms for the duration of the works to treat and contain any contaminated silt and water that escaped from the vacuum suction during the jetting process. The separate discharge pipes for the drain lines north and west of Bedwell Brook were confirmed through excavation of the second pipe at the discharge location and observation of flows / discharges during the jetting of individual sections of the system.

The extent of the drain clearance is shown on Figure 7. Drain Clearance Locations (Drawing No: A1-14890-3011), with typical photographs shown in Appendix E. Samples of sediment and water retrieved from the jetting process were submitted to the DETS laboratory for analysis (see Tables 14 to 16 and Appendix M).

Drains originally serving the area to the south of the WWU garage were severed and removed during the Area AC2 excavation works and not replaced. Drains along the central roadway through the Area AC2 excavation area (north of the garage) were severed and removed, but later replaced and reconnected with the system during roadway reinstatement. All other drainage was retained as found at the commencement of the works.



3.5.3.2 Pond 2 (Area AC3)

Pond 2 is an artificial surface water pond receiving surface water drainage from the southern site surface water drainage network (Flogas Compound and WWU Workshops). The pond has a minimal natural catchment around it and is provided with a single outlet pipe into a shallow artificial channel that leads down the natural slope into the Bedwell Brook, approximately 50m upstream of the railway embankment culvert entrance. The overflow channel only flows intermittently, principally during high rainfall events. The Pond 2 outlet pipe was almost completely choked with vegetation / silt at the commencement of the remediation works.

The extent of Area AC3 remediation works are shown in Figure 8. Area AC3 Remediation Plan (Drawing No: A1-14890-3006). Remediation works commenced with the dewatering of the pond using a large surface pump, provided with a fine mesh intake rose, suspended just above the pond base by a tracked excavator machine (that undertook subsequent sediment excavation works). Water was discharged into the adjacent overflow channel and allowed to drain down the slope into Bedwell Brook (as might happen during natural rainfall events). Water inflow to the pond during this task was minimal due to dry weather in the preceding days. Dewatering was supervised by the nominated ecological clerk of works (ECOW), who (working under the terms of the works ecological licence) undertook the relocation of a small number of newts and other amphibians found in the exposed sediments / vegetation debris.

No fish were present; the only other animal life found within the sediments were large diving beetles and two larvae, which were transferred to the overflow channel outwith the newt fenced area.

Inflow into the pond was then contained within a small clay dam around the drain discharge pipe and the pump intake placed into a sump within the contained area, to over-pump water directly to the overflow channel during the sediment removal works.



Loose sediment and residual water in the base of the pond was then mechanically excavated by backhoe excavator provided with a large, wide toothless bucket. Sediment / water was transferred to the Area AC2 treatment facility by dumper. Excavation was continued down to natural clay strata (soft, pale brown plastic clay) that underlies the whole pond area. The existing outlet pipe was exposed and retained in-situ. The overflow channel between the outlet pipe and the newt fencing boundary was also excavated down to natural clay, forming a short, narrow secondary pond feature immediately upstream of the undisturbed overflow channel beyond.

The excavation revealed two old clay field drains just beneath the base of the pond, one of which was dry, the other contained a small amount of oily / tarry water and sediment that oozed out into the excavation as the pipe was broken. The drain was excavated back to the western perimeter of the excavation area and no further discharge was observed. The exposed pipe end was rammed with a plug of natural clay, prior to burial beneath a placed clay layer (approximately 0.5m thickness). The other field drain was plugged in a similar manner, but not buried.

On completion of the sediment excavation, the pond perimeter was graded to as gentle a slope as practicable and the drain discharge dam was removed to allow water back into the pond. Due to high rainfall overnight, the pond was approximately two thirds full again by the following morning, with overflow through the outlet pipe commencing some two days after that.

The drain discharge pipe outfall was reinforced with cement sand bags, while the overflow pipe did not require any additional repair or alteration.



3.5.3.3 Bedwell Brook (Area AC4)

Bedwell Brook is a small surface water course originating in open countryside to the southwest of the site and flowing through the site area between two culverted sections, one (upstream) through the embankment that was constructed to take the former railway line connection into the main site area, the other under the current site access road that enters the site area at the south eastern corner.

Surface water drainage (from the main site area and the main site entrance roadway) discharges to the brook from two pipe outfalls located at the top of a concrete spillway on the northern bank, approximately 25m downstream from the railway embankment culvert exit. The brook flows in an excavated, steep sided channel, with soft sediment in the base and no emergent vegetation, although there were a number of natural dams formed from fallen branches and floating debris at various points between the two culverts. The downstream culvert entrance is provided with a metal bar trash screen that is also typically choked with vegetation debris.

The extent of Area AC4 remediation works are shown in Figure 9. Area AC4 Remediation Plan (Drawing No: A1-14890-3007). Prior to sediment removal, a temporary access road (crushed concrete from the Area AC2 excavations) was installed along the northern bank to a point approximately 30m downstream of the surface water drain discharge spillway. At the end of the road, a polythene sheet liner was placed into the channel and crushed stone placed on top.

The sheeting was then wrapped around the placed stone and anchored with more stone on top, forming a temporary dam / crossing point, and resulting in the rapid dewatering of the channel between the dam and the downstream culvert entrance, although a number of small, shallow pools of water remained due to the uneven profile of the channel bed.



A large capacity surface water pump was installed on the southern bank of the channel opposite the dam, with an intake rose placed in a natural pool formed by an undisturbed vegetation dam, immediately downstream of the railway embankment culvert exit. Water was pumped from this pool through layflat hose that discharged directly into the concrete culvert pipe leading under the main access road at the downstream site boundary. Water levels in the upstream pool were quickly lowered sufficiently to cause a reversal of normal flow direction in the channel, such that water entering the channel from the Area AC4 surface water drain discharges (that run continuously, even during dry weather) were also intercepted and pumped away.

Sediment and residual water was then excavated from the dewatered channel (downstream of the crossing point dam) using a backhoe mini-digger provided with a wide toothless bucket. Initial excavation was limited to visible modern loose sediment deposits and vegetation debris (up to approximately 300mm thick) that was releasing globules of black tar / oily sheen to the standing water. After the first excavation pass, very small seepages of black tar were observed in distinct sections of the channel and further excavation (~150mm deep) was carried out +/- 5m of these visually identified sections. Sediment removal was ultimately constrained by the profile of the channel banks and the reach of the machine, combined with the need to avoid the creation of dangerously deep pools. Historical basal sediment deposits were, therefore, not entirely removed and no natural strata were exposed in the base of the channel by the works. Excavated sediments and water were transferred to the Area AC2 treatment facility by dumper.

Subsequently, a second temporary dam was created using clayey soils excavated from the southern bank, immediately upstream of the surface water drain discharges (which were themselves temporarily diverted using cement sand bags, to flow into the stream channel upstream of the second dam).



The section between the two dams was then largely dewatered using the main surface water pump, followed by a second smaller capacity surface pump that discharged the silty residue from the dewatered section to ground on the southern bank (to avoid discharge of heavily silted water to the main channel).

Sediment (approximately 300-400mm thick) and residual water were then excavated from the channel between the two dams in the same way as for the main section described above.

This process revealed that the entire channel in this area was underlain by concrete, which extended up the northern bank to form the drain discharge spillway and also extended to the west as far as the temporary access road / downstream dam crossing point. It is assumed that this concrete was originally placed to prevent erosion of the northern bank / tip face by both flows in the Bedwell Brook and discharges from the surface water drains. The concrete lining was left undisturbed / undamaged by the sediment removal process.

On completion of the sediment excavations, the temporary dams and access road materials were removed and normal flows re-established in the channel. The surface water drain discharge pipe outfalls were reinforced using cement sand bags and the existing concrete spillway was retained in an unaltered state.

3.5.4 Ex-situ Treatment

The ex-situ treatment of contaminated excavation arisings from Area AC2 was carried out by a specialist treatment contractor, HBR, in a designated and separate secure compound within the main Maelor Works site (see Figure 5). This compound was also used for the temporary stockpiling of segregated concrete removed from the excavation area, along with stockpiles of crushed concrete / screenings following the mobilisation of a crusher to the site once all concrete break-out was complete.



The HBR treatment process was conducted under the terms of an Environmental Permit (for mobile plant – see Section 6 for details) and consisted of the carefully controlled mixing of the contaminated excavated materials with a specific blend of treatment reagents (ground granulated blast furnace slag (GGBS) and quicklime). The treatment process was designed on the basis of the findings of the treatment trials conducted during the Stage 1 site investigation phase and reported in detail in IKM REP005.

HBR treatment plant consisted of:

- 1no. WIRTGEN WR 2500 SK RECYCLER (specialist plant for the rotavation of treatment materials and the controlled addition of treatment reagents);
- 1no. 21ton Excavator Self Drive (for the handling of materials delivered for treatment / being transferred for backfill);
- 1no. Silo (lime storage);
- 1no. Silo (GGBS storage);
- 1no. 4,500ltr Diesel Fuel Tank;
- 1no. Rotating Laser Tripod (for the surveying of treatment pads);
- 1no. Tractor and water bowser (for water addition to treatment pads and general dust suppression).

Treatment pads in the order of 300mm thick were prepared using standard excavation equipment and the treatment reagents were spread onto the pad surfaces and mixed-in using bespoke rotavation plant (Wirtgen Soil Mixer). Water was added during treatment / mixing to optimise the stabilisation reactions and to control dust.



A sacrificial layer of excavation materials was maintained immediately above the original tarmac / concrete surface of the treatment compound until the last treatment batch was processed. This was to protect the compound surface from damage by the rotavation plant. The progress of treatment reactions was monitored closely by HBR operatives, and samples recovered for leachate testing. On completion of each batch, as notified by HBR, treated material was lifted by standard excavation plant and transferred back to the Area AC2 excavation area for immediate backfill or temporary storage (in separate stockpiles).

Samples of treated material were also obtained by IKM staff for on-site testing to monitor the levels of contamination in excavation materials (to compare to visual observations and provide comparative data to the basal clay sampling programme).

Material streams designated for treatment were:

- Visibly impacted made ground and granular alluvium direct from excavation areas or temporary stockpiles that had been screened / riddled to remove oversize materials (mainly concrete fragments, intact brickwork, pipework and large clumps of natural clay);
- Fine residues from screening and crushing (within excavation areas or stockpiles in the treatment area);
- Excavated sediments directly from Bedwell Brook and Pond 2;
- Sediments flushed from surface water drains during the drain clearance works.

Each prepared treatment pad was surveyed and numbered sequentially (Batch 1 through to Batch 20) and all records and samples were referenced to those individual batch numbers. Volumes of materials / reagents added to each batch were recorded in HBR tracking sheets that are presented in Appendix F.



As soon as the treatment process was completed to the satisfaction of the HBR site manager (based on visual inspection, observation of mixing process and spot sampling), the treatment pad was cleared for lifting and transfer directly back to the Area AC2 excavation, thereby making way for the next treatment batch. Treated materials were typically tipped directly into a designated part of the excavation void for levelling and compaction in accordance with the procedures described in Sections 3.5.2.5 and 3.11.2. Occasionally, temporary stockpiles of treated materials were formed within Area AC2 awaiting appropriate completion of break-out of structures and impacted soil excavations.

3.6 Contamination not Discovered by Investigation Works

The only contamination that was additional to that identified and targeted in the Remediation Design Report was the temporary appearance of free phase tar in two of the newly installed groundwater abstraction wells in Area AC1.

Free phase hydrocarbon liquids (DNAPL) were observed in the drilling spoil from borehole AB1 (Geo² RW1), while black, liquid tar entered borehole AB2 after approximately one week of water abstraction (no indications were observed in drilling spoil or water abstracted prior to that time). Water from this location continued to have an oily sheen and tarry odour for three weeks after the free phase tar had disappeared from abstracted water; the odour alone persisting to the cessation of abstraction from this location. Water abstracted from AB1 did not display any visual or odorous indications of contamination at any point during the works.

The status of hydrocarbon contamination within AB1 and AB2 was monitored as part of the regular inspection and sampling programme conducted during the groundwater abstraction works. The practical response to this additional contamination issue is described in the following section. On-site testing of the abstracted water from each borehole was used to monitor the concentration of hydrocarbons with time throughout the remediation works, as discussed in Section 4.



3.7 Remediation of Additional Contamination

The unexpected appearance of free phase hydrocarbon contamination within Area AC1 was restricted to two of the four newly installed boreholes in the southern section of the area and remote (in excess of 50m) from the site boundary. No free phase contamination has ever been observed in any of the ten other regularly monitored boreholes in this area, including those between wells AB1 and AB2 and the site boundaries.

Groundwater abstraction was continued up to the shutdown of the WTF and free phase hydrocarbons did not make a re-appearance in either well AB1 or AB2 during that time (or in subsequent post-remediation monitoring visits). Concentrations of hydrocarbons in the abstracted water showed dramatic reductions over the abstraction period and in line with visual / olfactory observations (see Table 6 for details).

It is therefore concluded that the observed contamination was restricted to a small scale accumulation of free phase tar within a localised gravel channel, the edge of which was intercepted directly by well AB1 only. Initiation of abstraction in AB2 drew in a small amount of free phase hydrocarbon, but the source was quickly exhausted (and never reached AB1).

This additional identified contamination was therefore considered to be insufficient to require any change to the overall treatment approach for Area AC1 (see Sections 4.2.1, 4.7 and 5.1.1 for details).

3.8 Residual Contamination

3.8.1 Area AC2

All identified underground tank structures were uncovered / exposed during the excavation process, which extended to include all operational areas of the former gas by-product processing works to the west and south of the former main power station (now the Training Centre) / CWG (now partially occupied by the WWU garage) buildings. It is noted that the peripheral roadway around the southern and western sides of Area AC2 was present throughout the operational history of the site and no by-product handling is suspected beyond this road at any point.



Similarly, no sign of significant contamination has been identified in any investigation location beyond this road, leading to its adoption as the southern and western limit of excavation in the remediation design.

However, it was noted that where the granular alluvium strata extend beyond the site excavation limits, it was possible for small volumes of mobile tar and associated groundwater to travel beyond the excavation area. Residual free phase tar contamination was visible as centimetre scale basal layers within gravel channel features exposed in some excavation faces, where significant free phase tar had migrated from the main source features within the former processing area. These localised and small scale features were observed in Grid Squares D3 on the eastern boundary, beyond sheet piling and G2/H3/H5 on the western and southern boundary, beneath shallow made ground that underlies the perimeter roadway.

Two similar features were also visible in the eastern and northern excavation faces to the west and south of the WWU garage building (due to the general northeast-southwest alignment of the gravel channels). Thin (similar centimetre scale) black stained horizons (but no free phase) had previously been observed in boreholes drilled inside the garage and under the training centre building, all placing a limit of approximately ten metres (laterally) on the extent of residual contamination anywhere to the east of Area AC2.

As noted above, no free phase, or significant dissolved phase, contamination has been encountered during any previous investigations to the south or west of the perimeter roadway that marked the edge of excavations in the southern and south western sectors of Area AC2. Residual tar in the base of gravel channels beyond the excavation area is therefore considered insignificant in terms of absolute and comparative (to that excavated) volume and pollution potential. The location of known residual contamination within Area AC2 is shown in Figure 10. Residual Contamination Plan (Drawing No: A1-14890-3010).



Likewise, the temporary sheet piling necessary to stabilise the road and buildings (training centre and garage) and to protect known service corridors to the east of the excavation area, prevented excavation of any contaminated made ground / natural granular alluvium between the excavation area and the buildings. It is noted that site investigation locations within and around the training centre building confirm the absence of significant free phase contamination in the gravel strata in those locations and there was no obvious seepage or ingress of significant hydrocarbon product from behind the exposed piles during excavations. It is therefore considered that there is no significant residual contamination along the eastern boundary of the excavation area, although small volumes of tarry made ground or basal gravels can be anticipated beneath the roadways, similar to those along the western and southern perimeters.

These residual contamination areas do not constitute a significant risk to site users under the existing site use scenario as they are not exposed at the surface and have insignificant volatile content / vapour emission potential, but their presence would need to be taken into account during any future works that involved disturbance of the ground in these areas (such as buried service maintenance or replacement).

Further details of residual contamination beneath the Training Centre and WWU Garage buildings are provided in the Area AC and Garage Supplementary Investigation factual reports (IKM REP002 and IKM REP006 respectively).

3.8.2 Area AC1

Dissolved phase contamination in groundwater to the north of the former spent oxide bunker was not included in the groundwater abstraction programme as originally planned, due to licensing delays and pump unavailability / loss. Consequently, shallow groundwater in this area (as far as the northern and western site perimeter) remains impacted by low level dissolved contamination, previously assessed as resulting from the historical leaching of contaminants in made ground and natural granular alluvium in Area AC2 to the south.



The main source areas for this contamination (the WWU Compound / Area AC2 excavation area and associated Area AC1 groundwater plume) have been effectively removed by the remediation works. Monitoring of groundwater quality within the northern sector of Area AC1 and adjacent surface water drainage (French Drain) has demonstrated an absence of any significant impacts beyond the site boundaries.

Groundwater in this area will be subject to ongoing natural attenuation, previously assessed as part of the site investigation phase and by comparison against samples from the southern section of Area AC1, closer to the identified sources. Ongoing attenuation is anticipated through dispersion, adsorption and dilution (by up hydraulic gradient groundwater flowing into the area from uncontaminated parts of the site) within the granular made ground and natural alluvium.

Data on the quality of the residual groundwater to the north of the abstraction area and within the abstraction area is provided by the testing results from monitoring throughout and after the remediation works (see Section 4.2.1 and 4.2.6).

It is therefore considered that due to the removal of the main historical sources of contamination, the low concentrations of key dissolved contaminants in established perimeter monitoring locations and the absence of any significant impacts beyond the site boundary, no further remediation or monitoring of the residual dissolved phase contamination in the north of Area AC1 is required.

3.8.3 Area AC4

A small amount of historical sediment remains in the Bedwell Brook channel between the concrete lined section and the access road culvert. This sediment was previously in contact with visibly impacted sediments and contains detectable concentrations of residual hydrocarbons, although visible contamination / oily sheens are absent, even during disturbance of the remaining sediments.



The residual sediment was subjected to sampling and testing, with the results discussed in more detail in Section 4.2.5 below. This section of the Bedwell Brook was also subject to water and sediment monitoring as part of the peripheral monitoring programme (Section 4.2.6), with no significant downstream impacts identified during or after the sediment remediation works.

Given the remediation of the primary contamination sources for this section of Bedwell Brook (site surface water drainage leading from Area AC2), the low concentrations of key contaminants detected in water samples and the absence of any reported, significant impacts downstream of the site access road culvert, no further remediation or monitoring of this sediment is considered necessary.

3.9 Engineering Work (including Relocation of Services)

No permanent engineering or service relocation work was carried out as part of the remediation works.

Temporary support to excavation faces (and thereby protection of underground services, roadways and the Training Centre and WWU Garage buildings beyond) was provided by steel sheet piling that extended up to 4m beyond the maximum depth of excavation along the northern and eastern perimeter of the excavation area. Piling was conducted by a specialist sub-contractor (Sheet Piling (UK) Limited) using hydraulic push techniques.

Sheet piling along the eastern excavation boundary (Grid Square C4), resulted in the shearing of a steel end valve / capped live water hydrant pipe (not marked on service plans). The damaged pipe was replaced by a new blanking plate outwith the excavation / sheet pile area by Morland Utilities Limited under direction from IHB. An incident report was prepared by IHB and agreed with NGPH, a copy of the report is included in Appendix G.

An unmarked, unrecorded and therefore unexpected, low pressure gas supply pipe (plastic so not detectable by CAT) was ruptured during excavation in Grid Square H7. The pipe was repaired in-situ by WWU and re-buried / provided with marker tape by IHB. Service plans for the site have subsequently been updated to include this pipe. An incident report was prepared by IHB and agreed with NGPH, a copy of the report is included in Appendix G.



Water main replacement work also resulted in the identification of a leaking hydrant on the external potable water supply main (to the north of the site boundary). The leaking hydrant was excavated and replaced by a new hydrant, details are provided in following sub-section 3.9.2 and Appendix J.

3.9.1 Demolition of Derelict Office Building

As part of the site works, a local specialist demolition contractor (M&JT Davies – see Table 1) was brought in to undertake the demolition and clearance of the disused former district office building. This demolition was not part of any contaminated land remediation works and was carried out under the terms of a separate demolition warrant from the WCBC (see Section 6 and Appendix C for details).

Prior to demolition, the building was extensively surveyed for the presence of asbestos containing materials (ACM) and subject to rigorous utility surveys to allow disconnection from all supplies. Details of the verification / confirmation of the disconnection actions are provided in Appendix H, with photographs taken at the time contained in Appendix E. Identified ACM were then removed and disposed of appropriately by a licensed contractor (see also Appendix H) prior to the main demolition works going ahead.

All demolition waste and recoverable or recyclable materials were removed from the site by the contractor in accordance with current waste management legislation (see Appendix H for details). The foundation slab for the building was left in place, with compacted rubble placed around the periphery to avoid steps / provide a smooth transition to surrounding areas.

3.9.2 Replacement of Water Main

Water supplies at the site had long been designated as non-potable due to contamination from unknown sources. As a result, the replacement of the mains water supply main into the site was specified as part of the overall works on-site (although the replacement main does not pass through any designated remediation areas, past or present). The work was not part of any contaminated land remediation works and was carried out as a separate contract by specialist sub-contractor, Morland Utilities.



At the request of NGPH, the scope of the mains replacement work was significantly expanded during the course of site works, with additional lengths of replacement water main being installed to various parts of the site (all to the east of the main remediation works and in areas not affected by any previously identified contamination issues). Mains replacement was only specified for external pipework, up to the point of entry into the various site buildings affected.

The replacement water mains did not pass through any active remediation areas and there were no visible or olfactory indications of significant contamination within the trenches excavated for the new pipework (see Appendix E for photographs). Nevertheless, given the history of the site and the contamination previously found in samples from within site buildings, the specification for the new water main was for a composite barrier pipe material to ensure that no contamination penetrated the new main in the future. Consequently, all excavated materials from the trenches containing the new pipework, were reused as backfill and no waste materials were generated for off-site disposal.

Following installation, all new mains pipes were pressure tested and sampled for microbiological contamination. All testing was conducted by specialist contractors working to Morland. All testing results were within acceptable levels for potable supply and all newly installed pipework is deemed acceptable for use as a potable water supply (water continues to be supplied to the main by the Dee Valley Water Company).

A plan showing the location of all newly installed mains is provided as Figure 15. Final Site Plan (Drawing No. A1-14890-3008). The accreditation details for the Morland personnel involved in the works are provided in Appendix J, along with the results of the pressure and water quality testing performed on completion of the installations. A photographic record of the works is also provided in Appendix E.



3.10 Excavation Photographs

A comprehensive photographic record of each element of the remediation works has been produced by IKM/IHB. All IKM/IHB photographs have been compiled onto a photograph listing table and burned to a CD, which forms Appendix E and is included in Volume II of this report. Selected photographs have been chosen to illustrate the following features of the works:

- Before and after surface conditions within each of the remediation areas (AC1-AC4);
- Typical ground conditions exposed in the main excavation area (to the north of the former main tar tank; immediately to the south of the tar tank; operational areas in the southern sector of the former gas processing works;
- Details of the surface water discharges to Pond 2 (Area AC3) and Bedwell Brook (Area AC4);
- Operational ex-situ treatment working area;
- Material stockpiles (clean surface aggregates, excavated untreated material; broken out concrete and visibly contaminated materials awaiting treatment);
- Remediation areas immediately after the completed excavation of contaminated made ground / sediments (Areas AC2, 3 and 4) and following backfill / reinstatement;
- Sequential views of the demolition works, including final surface conditions;
- Views of the trenches opened to allow laying of the replacement water main, along with details of the external connection / replacement hydrants at the site northern boundary.



3.11 Reinstatement and Compaction Works

3.11.1 Area AC1

Reinstatement in this area simply comprised the removal of all temporary plant (WTF and groundwater pumps / hoses) and temporary fencing. External site boundary fencing remained undisturbed and unchanged throughout the works. The newly installed abstraction wells remain in place and are available for future monitoring if required (although none is proposed / required as part of this remediation works), along with other historical wells. Abstraction wells were finished flush with the ground surface, while historical wells have steel headworks that protrude above the ground surface (~300-500mm above the ground).

3.11.2 Area AC2

All excavation areas were backfilled as soon as practicable using treated materials from the ex-situ solidification / stabilisation process and recovered untreated / crushed secondary aggregate. Excavation and backfilling was conducted on a progressive basis to avoid the need to leave unsupported deep excavations open for any length of time.

Treated materials were loose tipped after release from the treatment area and graded out in thin layers by tracked excavation plant and a specified compaction was achieved by use of self-powered vibrating roller. Backfilled materials were subject to geotechnical testing to demonstrate adequate strength / compaction had been achieved. The compaction specification (taken from the NGPH Core Specification) and geotechnical testing results are discussed in more detail in Sections 4.6 and 4.8.

Deep excavation areas (>2m deep) were provided with basal and intermediate layers of crushed secondary aggregate (site derived) to act as preferential flow paths for groundwater under and through the backfilled mass of treated material (which has a very low permeability). These drainage layers were a nominal 300mm in thickness and of similar transmissivity to the natural gravel layers that had been excavated as part of the remediation process.



The intention is that the minimal infiltration into the compacted and actively drained surfaces and minimal groundwater flow through the treated material, will minimise the leaching potential of the remediated site area (in addition to the action of the stabilisation treatment itself).

The surface of the backfilled area was further provided with a protective layer of at least 200mm thickness of crushed secondary aggregate (site derived) and reused granular aggregate that made up the majority of the original surface layer in Area AC2. This surface layer was graded out in thin layers by tracked excavator and further compacted and smoothed using the vibrating roller.

The presence of treated materials (including stabilised contamination) beneath the surface cover layer is indicated across all the backfill areas by the placement of an orange plastic warning mesh between the backfilled material and the surface cover layers.

The central roadway through the excavation area was reinstated along its original alignment to standard highway specification, with a bitumen bound top layer.

3.11.3 Area AC3

The northern bank of Pond 2 was graded to an even slope by a tracked excavator and the exposed clay soil surface left to re-vegetate naturally. Other banks for the pond were not disturbed during the remediation works. No materials were imported to the remediation area at any time.

The discharge pipe for the surface water drain inflow was excavated and reinforced using cement filled sandbags around the exposed clay pipe. A stepped spillway was formed below the discharge, cut into the natural clay bank.

A small number of purchased (nursery bred) water plants were placed into the pond once all the remediation works were completed. Brash and small timber logs from the initial de-vegetation were used to construct small animal / invertebrate shelters on the land to the north of the pond. All ecological fencing materials were removed from around the remediation area and disposed of off-site.



3.11.4 Area AC4

All temporary road and dam materials were removed from the area on completion of the sediment excavation works. The road corridor itself remains open to allow access along the northern channel bank for normal maintenance activities and access to buried gas pipelines to the west.

No materials were imported into the channel itself, although natural deposition of loose sediments quickly followed the re-introduction of water flow within the treated sections (including over the retained concrete lined section). Re-profiling of the channel banks proved impractical due to machine and access constraints, so the banks remain relatively steep and un-vegetated, as per commencement of the works.

Brash and small timber logs from the initial de-vegetation were used to construct small animal / invertebrate shelters on the land to the north and south of the brook channel. All ecological fencing materials were removed from around the remediation area and disposed of off-site.

3.12 Materials Management Plan

No significant deviations from the IHB Materials Management Plan occurred during the works. A copy of the plan is included in this report as Appendix K.

No restoration or backfill materials were imported onto the site, only retained and recovered site materials were used (following treatment and processing (screening / crushing) as appropriate.

Whilst every effort was made to reuse and recycle materials, some waste arisings needed to be treated, recovered or disposed of off-site including:

Segregated demolition materials from the former office building that was demolished as part of the works. Asbestos containing materials, timber and roofing felt, metal, cable and general blockwork / brick masonry debris were removed off-site by the specialist demolition contractor for recycling / disposal at suitably licensed facilities. Copies of receiving site licences and the waste transfer notes produced during the demolition are provided in Appendix H.



Metal recovered directly from the Area AC2 excavations and from screening / crushing of concrete in the ex-situ treatment area was also dispatched for off-site recycling. Copies of receiving site licences and the waste transfer notes produced during the demolition are provided in Appendix H.

General waste arising from the remediation works site compound and offices was removed by licensed waste management contractor at regular intervals throughout the works period, along with sewage from the compound toilets.

Small quantities of potentially or visibly contaminated waste (coveralls, gloves and wipes) from the site decontamination unit and site testing (used sample vials and soil sample materials, gloves and wipes), were placed in a separate waste container for return to IHB operations depot and separate disposal from there.

Residual sediment and used filter media from the WTF, were disposed of at licensed facilities as per the Geo² decommissioning reporting (Appendix L).

Used newt fencing and bird deterrent tape removed from areas subject to ecological management / licensing. Details of ecological management decommissioning are provided in the Protected Species Licence sign-off report (IKM 2015 REP002).



4. VERIFICATION REPORTING

4.1 Summary of the Verification Plan

The verification process was tailored to each remediation area, reflecting the different conditions and remediation techniques being employed.

4.1.1 Area AC1

Verification focused on confirmation that groundwater abstraction was creating a cone of depression around the abstraction wells, and thereby drawing in contaminated groundwater from the surrounding strata. The total volume of groundwater abstracted was determined through measurements of the flow from each abstraction borehole and a record of the length of time that pumping was active.

Monitoring of water level and quality in nearby monitoring boreholes allowed the lateral extent of remediation to be calculated and compared against baseline / historical conditions.

Area AC1 also hosted the WTF treating groundwater abstracted from the Area AC2 excavations (the principal source zone for the dissolved phase contamination being remediated in Area AC1). Visual inspection of the treatment stream and discharge was conducted at least weekly by site supervisors, with further monitoring and sampling of the effluent being undertaken by the specialist contractor during fortnightly maintenance visits. Measurement of volumes of water passing through the WTF as a whole were recorded daily (this includes abstracted groundwater, volumes of which were calculated separately).

4.1.2 Area AC2

Verification of excavations was primarily based on the visual inspection of the phased excavations, with a photographic record to demonstrate that all tar / hydrocarbon impacted materials had been removed and that uncontaminated / undisturbed natural strata had been reached. The extent of excavations was recorded through a progressive programme of site surveying and the production of excavation record plans on a regular basis.



Spot samples of the basal and wall materials were taken to provide quantitative data on the absence of tar / hydrocarbons in visually clean materials. The frequency of sampling was varied depending on the condition of the exposed clay and the severity of overlying contamination, coupled with experience gained during initial intensive sampling programmes (1 per 10m² of excavation face). Additional quantification was undertaken of occasional visible penetration of tar streaks along clay fractures and the diffusion of contaminants into clay / silty clay materials leading to a phenolic tarry odour in visibly clean materials.

Retained structures were recorded through surveying of location and profile, along with a photographic record of each structure and surrounding strata.

Site survey data was used to calculate volumes of materials sentenced for ex-situ treatment, and stockpiled as broken out concrete and other oversize materials.

Representative sampling and on-site testing (4 to 6 samples per batch) was conducted on each batch of ex-situ treatment materials to provide a record of the total contamination levels within the excavated spoil. Further samples (one sample per batch) were taken and tested after a curing period to determine the leachability of the solidified/stabilised contaminants. Leachate testing consisted of both traditional testing on crushed samples in agitated 10:1 water: soil conditions (as per BS EN 12457) and more representative “tank test” conditions, using immersed sample blocks in non-agitated conditions (see IKM 2014 REP005 for details).

Results of excavation spoil testing were compared against historical site investigation testing data to demonstrate the validity of pre-remediation risk assessment and treatability trials.

Results of leaching tests were compared against treatment targets produced from modelling of treated backfill within the excavation area and a compliance point at the nearest site boundary (the French Drain along the western fence).



Additional sampling and visual inspection was conducted on stockpiles of segregated aggregate, visually un-impacted natural materials and crushed concrete fines to demonstrate the absence of significant contamination in these materials prior to their reuse on site. Samples were taken from across the surface of each stockpile where access was possible, with 4 to 6 samples being obtained from each stockpile for on-site testing.

Backfilled materials were subject to compaction and geotechnical testing (plate bearing tests) to determine the initial strength of the treated materials as placed (i.e. prior to long term cementation reactions being complete).

The inspection and screening of excavated material for radioactivity produced extensive inspection / screening diary records and associated calibrated instrumental radioactivity measurements (see Appendix D).

4.1.3 Area AC3

Verification of sediment excavation was provided through the surveying of the excavated pond base and recording of volumes of excavated material transferred to the ex-situ treatment area. A photographic record was also made of the completed excavation and the subsequent re-filling of the pond (see Appendix E).

Three samples were taken from the freshly exposed basal clay and tested to confirm the absence of any significant contamination in these materials.

Removal of contaminated sediment from the associated surface water drains was verified through a diary record of the attendance of the specialist drain clearance contractor, including a note of the individual lengths of drain subject to cleaning, and the production of a site plan showing the same. A photographic record was also made during the works (see Appendix E).

Post remediation samples (sample designation 3A) were taken of the discharge from the cleared surface water drainage to demonstrate the absence of any significant new contamination from this source (the only input to the pond).



4.1.4 Area AC4

Verification of sediment excavation was provided through the visual inspection of the channel and the remaining sediment deposits, with physical disturbance used to demonstrate the absence of free tar / hydrocarbons within the material (compared to clearly visible / easily induced response prior to remediation).

The excavated channel base was surveyed and a record made of volumes of excavated material transferred to the ex-situ treatment area. A photographic record was also made of the completed excavation and the subsequent re-establishment of flow in the brook channel.

Samples (sample designation B1 to B9) were taken at intervals of between 5 and 10 linear metres, from the freshly exposed basal sediments and tested to demonstrate and record the level of residual contamination in these materials.

Removal of contaminated sediment from the associated surface water drains was verified through a diary record of the attendance of the specialist drain clearance contractor, including a note of the individual lengths of drain subject to cleaning and the production of a site plan showing the same (Figure 7). A photographic record was also made during the works (Appendix E).

4.1.5 Peripheral Receptor Monitoring

Samples of surface water, sediments and groundwater were taken from selected locations around the periphery of each remediation area. Samples were tested for the full range of parameters in the National Grid suite and results compared against data obtained from similar or identical locations during the historical site investigations.

Samples were taken immediately before the commencement of remediation activities, one week after completion of active remediation works and a final round conducted three months after the completion of remediation works, to demonstrate the long term status of the peripheral receptors.



Selected samples were also taken during the course of the site works period to establish normal short term variations in water quality at locations within active remediation areas, and those awaiting commencement of works (see following sections for details).

4.2 Description of the Verification Results

4.2.1 Area AC1

Rest Water Levels for each of the abstraction boreholes within the Area AC1, along with those for nearby existing monitoring locations, were measured at least weekly throughout the groundwater abstraction period. Water level data and associated graphical presentations are shown in Figure 11. Groundwater Contours during Abstraction (Drawing A1-14890-3009) and Figure 12. Area AC1 Water Level Charts. It is clear that the pumping from the wells caused a lowering of the water levels in each of the actively pumping wells and a detectable reduction in water levels in each of the adjacent monitoring boreholes.

The maximum reduction in water level was some 1.60m, with water level reductions being detected in all abstraction boreholes and the surrounding monitoring wells. It is concluded from this data that groundwater from across the Area AC1 was being drawn into the abstraction wells by the temporary hydraulic gradients formed by the pumping effort. More water would have originated from the area to the south of the former oxide bunker due to the physical barrier to groundwater flow formed by the underground bunker structure and the concentration of the abstraction wells within the southern sector (i.e. nearest the identified source areas – WWU compound and Area AC2 further to the south).

Volumes of water abstracted have been estimated through the periodic measurement of discharge rates from individual wells, a record of the time of operation of the abstraction pumps and daily measurement of the volumes of treated water being discharged to foul sewer. Table 5 shows the results of these estimates.



Table 5: Groundwater Abstraction Volume Estimates

Location	Estimated Abstraction Rates (m ³ /day)			Operating Time	Estimated Total Volumes
	Min	Max	Average	(days)	(m ³)
AB1	4.3	8.3	6.1	67.50	412
AB2	9.1	17.3	14.3	71.25	1,020
AB3	0	<0.1	0		
AB4	7.2	12.1	10.1	71.25	716
Total	25.0	32.0	29.2		2,148
Sewer Discharge*	10**	80	36	79	3,011

Notes: * - measured volumes, ** - when discharge was running.

Water quality within Area AC1 (abstracted water and in-situ groundwater) was monitored and sampled before, during and after the remediation works, with groundwater being sampled from selected existing wells and surface water run-off collecting in the western boundary drain (French Drain), also being sampled from an access chamber just outside the northwest corner of the site area (Location SW6).

Key contaminants of concern previously identified within the water in Area AC1 were cyanide, phenol, ammonia and tar related hydrocarbons (tested as TPH, EPH and PAH). Additionally, field parameters—, (pH, dissolved oxygen (DO), oxidation / reduction potential (Redox - Eh), conductivity (EC), and temperature) were measured to establish typical groundwater quality profiles for locations impacted to varying degrees.

Table 6 shows the how the concentrations of these key parameters vary, at locations within Area AC1 across the remediation period.



Table 6: Area AC1 Groundwater Testing Results

Location	AB1					AB2					AB4					MW11-02					MW99-104				
Parameter	BTEX GRO (mg/l)	DRO (mg/l)	TPH (mg/l)	Total Aro (mg/l)	16 EPA PAHs (mg/l)	BTEX GRO (mg/l)	DRO (mg/l)	TPH (mg/l)	Total Aro (mg/l)	16 EPA PAHs (mg/l)	BTEX GRO (mg/l)	DRO (mg/l)	TPH (mg/l)	Total Aro (mg/l)	16 EPA PAHs (mg/l)	BTEX GRO (mg/l)	DRO (mg/l)	TPH (mg/l)	Total Aro (mg/l)	16 EPA PAHs (mg/l)	BTEX GRO (mg/l)	DRO (mg/l)	TPH (mg/l)	Total Aro (mg/l)	16 EPA PAHs (mg/l)
Dates																									
26/03/15	ND	54.7	54.7	17.9	0.83	ND	141.3	141.3	109.4	47.6	ND	0.60	0.60	0.60	ND						ND	3.30	3.30	0.86	0.04
02/04/15	ND	40.1	40.1	7.5	0.29	ND	27.5	27.5	27.5	3.1	ND	0.31	0.31	ND	ND						ND	3.60	3.60	2.90	0.13
10/04/15	ND	33.9	33.9	8.1	0.32	ND	185.0	185.0	39.1	1.5	ND	0.31	0.31	ND	ND	ND	46.4	46.4	ND	ND	ND	6.10	6.10	1.30	0.05
16/04/15	ND	24.2	24.2	5.8	0.23	ND	91.4	91.4	52.0	1.9	ND	0.80	0.80	0.80	0.09	ND	26.8	26.8	12.9	0.52	ND	0.31	0.31	ND	ND
16/04/15						ND	59.0	59.0	57.0	2.1	ND	0.31	0.31	ND	ND						ND	0.31	0.31	ND	ND
24/04/15	ND	4.8	4.8	3.6	1.70	ND	26.0	26.0	26.0	2.7	ND	0.74	0.74	0.74	0.08	ND	40.7	40.7	24.6	2.80	ND	3.90	3.90	1.50	0.06
24/04/15	ND	4.8	4.8	3.6	1.60	ND	210.9	210.9	31.7	1.4	ND	0.84	0.84	0.84	0.10										
30/04/15						ND	20.6	20.6	20.6	2.2	ND	ND	ND	0.06	ND	ND	28.4	28.4	8.7	0.35	ND	0.72	0.72	0.72	0.08
07/05/15	ND	2.9	2.9	2.1	0.98	ND	51.6	51.6	45.7	22.4	ND	ND	ND	ND	ND	ND	28.9	28.9	28.9	3.20	ND	0.64	0.64	0.64	ND
15/05/15	ND	3.0	3.0	3.0	0.33	ND	22.1	22.1	22.1	2.3	ND	0.31	0.31	ND	ND	ND	2.6	2.6	ND	ND	ND	0.74	0.74	0.37	0.02
07/15																									
Parameter	pH (units)	EC (uS/cm)	DO (%)	ORP (mV)	Temp (°C)	pH (units)	EC (uS/cm)	DO (%)	ORP (mV)	Temp (°C)	pH (units)	EC (uS/cm)	DO (%)	ORP (mV)	Temp (°C)	pH (units)	EC (uS/cm)	DO (%)	ORP (mV)	Temp (°C)	pH (units)	EC (uS/cm)	DO (%)	ORP (mV)	Temp (°C)
Dates																									
25/03/15	7.03	1645	0.9	-94	10.0	7.84	1887	0.0	-195	9.9	7.03	1441	0.8	-111	9.4	7.30	2266		-53	8.5	7.05	1596	37.5	-92	9.8
02/04/15	7.04	1379	0.2	-97	9.5	7.21	1969	0.9	-123	9.6	7.60	1321	0.0	-110	9.6						7.00	1465	34.2	-76	10.0
09/04/15	7.07	1325	0.1	-105	11.0	7.24	1793	0.1	-122	11.4	7.00	1289	0.0	-122	12.5	7.17	2470	2.9	-26	10.2	7.20	1634	1.1	-89	10.9
16/04/15	7.29	1357	0.2	-102	11.8	7.17	1690	0.0	-128	10.5	7.05	1407	0.1	-112	10.4	7.30	2533	2.3	-47	9.0	7.01	1604	1.3	-75	10.6
23/04/15	7.18	1223	0.2	-97	12.6	7.26	1596	0.6	-118	12.3	7.03	1374	0.0	-116	13.2	7.46	2589	2.9	-105	12.2	7.32	1574	2.2	-99	12.1
30/04/15						7.21	1543	0.6	-117	9.9	7.23	1291	1.3	-104	9.2	7.36	2650	2.7	-73	9.1	7.34	1597	2.6	-99	10.2
07/05/15	6.35	1051	0.1	-75	10.5	6.62	1281	0.1	-114	10.1	6.66	1096	2.2	-94	10.5	6.84	2436	1.0	-60	11.2	7.00	1450	1.5	-91	11.2
15/05/15	7.15	1029	14.9	-112	10.2	7.02	1261	5.1	-118	9.7	7.09	1059	15.7	-113	9.7	7.34	2311	29.1	-81	9.8	7.04	1466	29.6	-86	10.1

Notes:

Blank cells indicate no sample available; ND – Not Detected; BTEX/GRO – C6-C10; DRO – C10-C35; TPH – C5-C35. Total Aro – Total Aromatic Hydrocarbons; 16 EPA PAH calculated from Total Aromatics by QED instrument.

EC – electrical conductivity, DO – dissolved oxygen, ORP – oxidation / reduction potential, Temp – temperature, all directly measured instrumentally.



Using estimates of groundwater volumes from the risk assessment reports, the volume of water removed from Area AC1 represents approximately 77% of the available groundwater within the made ground and alluvial aquifers in the locality. It is clear that water was drawn in from surrounding areas to replenish abstracted water and maintain groundwater levels at the measured elevations (as opposed to much lower levels that would have been observed otherwise).

The lowering of concentrations of key contaminants observed during the remediation is a result of the mixing of replenishing groundwater and the residual groundwater within the wider Area AC1. Following the removal of the key sources of the previously identified contamination, the concentration of key contaminants across Area AC1 would be expected to fall further without the need for any additional remediation efforts.

On this basis, the current status of contamination within Area AC1 is assessed in Section 5 of this report.

4.2.2 Area AC2

4.2.2.1 Visual Observations and Photographic Records

The core objective of the remediation within Area AC2 was to recover all significant free phase tar contamination that had been identified beneath the main tar handling areas of the former gasworks. Tar impacted soils and made ground were visually easily identifiable and contrasted strongly to the low permeability, plastic clay strata that formed the base of the majority of the excavation area. The absence of free product was also visually obvious within loose sands and silts that were exposed in the excavation side walls and base in the north and west of the excavation area.

The primary verification process was therefore the visual inspection of the excavation extents to confirm that all significant free phase impacted materials had been removed and that there was no indication of additional significant contamination beyond the excavation boundary.



A comprehensive photographic record was made to back up the visual observations, along with a detailed diary record of the works. Observations have demonstrated: the complete excavation of visibly contaminated materials from within the excavation area; and the presence of a low permeability clay seal beneath the entire excavation area, preventing the downward migration of free phase tar and associated contaminated groundwater.

Selected photographs, representative of each of the excavation area Grid Squares have been listed in Table 7. The full photographic record is presented as Appendix E.

Table 7: Area AC2 Photograph Listing

Photo File Ref	Grid Squares	Description
WK6(2)	A1/A2	Natural materials north of main tar tank. Proven free of visible / free phase contamination by additional trial pitting.
WK6(6)	A3	Sheet pile boundary of excavations.
WK6(7)	A2/A3	Main tar tank north wall and vertical rubble backfill layer.
WK6(9)	A3	Clay base and profile of natural granular alluvium exposed. Hydrocarbon from tar tank rubble surround running over clay surface.
WK6(47)	A3	Draining tar tank rubble surround to clay sump.
WK7(49)	A3/A2/A1	Placement of granular drainage on clay base prior to backfill of treated material.
WK7(75)	A3/A2/A1	Final excavation to north of tar tank, clay exposed and rubble tank surround removed.
WK7(22)	C2	Clay base exposed beneath secondary concrete structures adjacent to main tar tank.
WK8(48)	C3	Clay base under excavated concrete structures adjacent to tar tank south wall.



Photo File Ref	Grid Squares	Description
WK9(2)	C2/C1 D2/D1	Clay base exposed with unimpacted gravel layers left in-situ to south.
WK7(37)	D4	Clay base exposed with small gravel channels awaiting excavation.
WK8(12)	D3/E3	Clay base exposed following removal of made ground and gravel channels.
WK9(19)	E1/E2	Concrete foundations over sand and gravel with no significant contamination.
WK7(42)	E4	Clay base exposed following removal of gravel channels.
WK8(89)	F2/F3	Clay base after removal of concrete slabs and gravel channels to west of garage.
WK9(26)	F3/F4	Clay base under impacted made ground.
WK9(25)	F4	Clay base at sheet pile boundary, with thin impacted layer in overlying made ground assumed to extend under garage (matches findings of garage SI).
WK9(42)	F2/F3 G2/G3	Clay base and western wall free of visible contamination.
WK10(3)	F2/F3 G2/G3	Clay base exposed with deep concrete pad (retained) and deep north-south drainline.
WK10(7)	G2/F1	Western wall with thin layer of residual staining.
WK9(31)	G4	Isolated occurrence of tar penetration into clay.
WK11(28)	G4	Clay base and concrete foundations beneath garage.
WK12(10)	G5	Clay base and garage boundary.
WK10(40)	G2/H2	Clay base, western extents in sand and made ground under peripheral road to south.
WK10(56)	H2	Southwestern corner of excavation area.
WK11(15)	H4	Retained (backfilled) concrete structure.



Photo File Ref	Grid Squares	Description
WK11(23)	H3	Clay base and excavated north-south drainline.
WK12(1)	H4/H5	Clay base and retained concrete foundations.
WK12(6)	H4	Clay base and southern boundary (concrete structure).
WK12(33)	H6	Southern boundary and retained slab / foundations.
WK12(46)	H6	Eastern boundary and clay base.

Exposure of the retained northern tar tank walls and the absence of any free phase tar in the excavation to the north or west of the retained tar tank demonstrated that, as anticipated, no significant leakage from this source has occurred, either during gasworks operations or since (the contents of the tank have been removed in a well-documented previous remediation project).

Previous site investigations have further demonstrated that no significant free phase tar contamination exists in adjacent areas of the site, beyond the most recent excavation boundaries. The documented excavation therefore recovered all the significant free phase tar contamination within Area AC2.

4.2.2.2 Basal and Wall Sampling

In addition to the visual inspection of excavation faces and bases, sampling of the exposed natural soils and made ground was undertaken and those samples tested for tar related contaminants. The majority of testing was undertaken on-site using a validated UV fluorescence method (QED analyser) that is particularly sensitive to aromatic hydrocarbons, including PAHs. Additional cross check samples were tested at the same commercial laboratory used for all off-site testing during the works (DETS in Consett). Details of the QED analyser and the site testing validation work are provided in Section 4.9.3 and Appendix P.



The initial plan for the excavation base and wall sampling was for one sample per 10m² of exposed face, but the clear cut nature of the contamination front meant that this density of sampling was unnecessary. Reduced density sampling nevertheless continued for confirmatory purposes and the actual frequency of sampling was dictated by access constraints to the excavation base due to the depths reached and the relative instability of side walls formed within made ground and loose granular natural alluvium (gravels, sands and silts). Sample locations were recorded by the site surveyor and are shown on Figure 13. AC2 Excavation Grid Squares and Sample Locations (Drawing No. A1-14890-3002).

The results of on-site testing on basal samples are shown in Table 8, along with some data from excavated materials and exposed wall materials for comparison. The “Sample ID” column indicates whether samples are basal clay, disturbed excavation material, or exposed wall material as follows:

Basal sample: Sample ID comprised of “Grid Sq No.” + sequential “B” No.
(e.g. A1B1 – base sample 1 from Grid Sq A1)

Wall sample: Sample ID comprised of “Grid Sq No.” + sequential “W” No.
(e.g. F1W1 - wall sample 1 from Grid Sq F1)

Disturbed sample: Sample ID comprised of “Grid Sq No.” + sequential “S” No.
(e.g. A2S1 – disturbed sample 1 from Grid Sq A2).

The QED analyser is pre-calibrated and runs bespoke software to provide results for total aromatics (C5-C35) derived from the relative fluorescence (at selected target wavelengths) of the sample, along with calculated values for TPH and total PAH (US EPA16 compounds), based on the total aromatics result and the overall fluorescence spectra for the sample. The testing results (Table 8 below) demonstrate that as anticipated, no significant quantities of free tar or associated key hydrocarbon contaminants (PAHs) have penetrated the plastic clay strata beneath the excavation area. For further comparison, the testing results for visibly impacted materials subject to treatment, are presented in Table 10.



Table 8: Excavation Extents Testing Results

Grid Square	1			2			3			4			5		
	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)
A	A1B1	57	5.00	A2S1	850	8.50	A3S1	50	0.50	Outwith Excavation			Outwith Excavation		
				A2B1	12	0.21	A3B1	6	0.11						
B	B1S1	3,002	229.9	No samples – backfilled tar tank not disturbed						Outwith Excavation			Outwith Excavation		
C	C1B1	14	1.20	C2S1	756	119	C3S1	1,595	594	Outwith Excavation			Outwith Excavation		
	C1B2	28	0.30	C2B1	71	7.0	C3B1	81	1.30						
	C1B3	80	0.22				C3B2	86	1.00						
							C3B3	17	1.60						
							C3B4	6	1.30						
							C3B5	8	0.10						
							C3B6	18	1.90						
							C3B7	7	1.30						
D	D1B1	0.6	0.07	D2S3	6,270	883	D3S1	140	9.30	Outwith Excavation			Outwith Excavation		
	D1B1	19	0.30	D2B1	9	0.15	D3S2	87	8.70						
	D1B2	94	0.82	D2B2	7	0.12	D3B1	21	1.70						
	D1B3	5	0.16	D2B3	3	0.61	D3B2	25	0.58						
				D2B4	12	1.00	D3B3	65	6.60						
							D3B4	177	15.00						
							D3B5	22	0.51						
							D3B6	494	2.50						
							D3B7	53	10.60						
							D3B8	0.83	0.12						



Grid Square	1			2			3			4			5		
	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)
D							D3B9	7	1.50						
							D3B10	34	1.00	Outwith Excavation					
							D3B11	12	0.25						
							D3B12	4	0.83						
							D3B13	20	0.36						
							D3B14	15	0.30						
E	E1B1	19	1.90	E2B1	<0.63	<0.03	E3B1	295	1.20	E4B1	114	49.7	Outwith Excavation		
				E2B2	7	1.20	E3B2	14	0.26	E4B2	113	16.7			
				E2B3	56	21.70				E4B3	801	4.7			
										E4B4	159	63.1			
F	F1B1	0.9	0.06	F2B1	326	0.92	F3B1	1,005	6	F4B1	251	2.5	Outwith Excavation		
	F1W1	9	0.09	F2B2	84	1.00	F3B2	32	13.50	F4B2	628	2.2			
				F2B3	68	0.65				F4B3	29	1.5			
				F3B3	85	0.89	F3B4	148	1.50	F4B4	106	15.0			
				F2B4	616	3.00	F3B5	320	53.40						
				F2B5	717	4.20									
				F2B6	207	0.95									
				F2W2	14	1.60									



Grid Square	1			2			3			4			5			6		
	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)	Sample ID	TPH C5 – C35 (mg/kg)	16 EPA PAHs (mg/kg)
G	G1W1	1,313	220	G2B1	129	2.30	G3B1	396	155	G4B1	33	12.9	G5B1	62	0.54	G6B1	98	9.3
	G1W2	41	3.8	G2B2	31	0.56	G3B1	22	0.26	G4B2	192	0.69				G6B2	170	3.4
	G1W3	12,780	1,077	G2B3	10	4.20	G3B2	246	48.3	G4B3	98	8.70				G6W1	873	318
				G2B4	869	5.70	G3B3	18	0.30	G4B4	256	77.6				G6W2	3,578	237
				G2B5	629	2.70	G3B4	1,555	11.0	G4W1	11	1.20						
				G2B6	200	30.70				G4W2	31	12.7						
H				H2B1	582	4.20	H3B1	1,208	5.00	H4B1	279	1.30	H5B1	123	1.10	H6B1	54	1.0
				H2W1	45	8.60	H3B2	46	0.44	H4B2	14	0.41	H5B2	47	0.67	H6B2	2,231	6.5
				H2W2	190	2.80	H3B3	5	0.24	H4B3	2,463	6.20	H5B3	471	2.20	H6B3	480	2.4
							H3B4	105	0.64	H4B4	317	1.30	H5W1	9,949	3,135	H6W1	2,589	912
							H3W1	9,023	1,348							H6W2	60	25.5
																H6W3	10,896	406
																H6W4	244	26.7



4.2.2.3 Ex-situ Treatment Results

The amount of contamination that was recovered from the excavation area and subjected to ex-situ treatment was recorded by the survey of the treatment pads prepared for each batch of the solidification / stabilisation procedure. Table 9 shows the volumes of materials measured in each batch.

Table 9: Ex-situ Treatment Batch Volumes

Batch No	Pad No	Treatment Start Date	Total Volume (m ³)	Lime Added (tonnes)	GGBS (tonnes)	Volume Water (m ³)
1	1	17/04/15	294	35	35	74
2	1	20/04/15	166	20	20	62
3	1	21/04/15	165	20	20	39
4	1	23/04/15	160	20	20	45
5	1	24/04/15	161	19	19	56
6	1	27/04/15	160	20	20	56
7	2	28/04/15	144	19	19	56
8	1	29/04/15	175	24	24	68
9	2	30/04/15	158	19	19	68
10	1	06/05/15	144	18	18	56
11	2	07/05/15	140	19	19	56
12	1	08/05/15	212	27	27	45
13	2	14/05/15	135	17	17	45
14	1	15/05/15	165	21	21	45
15	2	18/05/15	129	14	14	56
16	1	19/05/15	152	18	18	45
17	1	21/05/15	199	20	20	45
18	1	22/05/15	60	12	12	23
19	1	17/06/15	170	17	17	56
20	1	17/06/15	262	16	16	56

Notes:

Batch 1 (single pad) included basal layer left in place under subsequent batches.

Batch 20 (single pad) included side bunds and original basal layer.

Pad 1 was the initial treatment area to the south of the compound.

Pad 2 was the second treatment area to the north of the compound.



Samples were taken from the treatment pads immediately after treatment for on-site testing for key tar related contaminants. Between four and six grab samples were taken from each pad to provide an indication of the variability of contamination within the mixed materials. Table 10 shows the maximum, minimum and average concentrations of key contaminants in the treated materials, along with the estimated overall mass of contaminants recovered from Area AC2 and treated by solidification / stabilisation. The contamination mass estimate is arrived at as follows:

- Typical density of graded treatment pad prior to mixing – 1,750kg/m³;
- Mass of each treatment batch – Measured volume x typical density;
- Mass of contamination in each batch – mass x average TPH concentration.

For Batch 6 and Batch 18 onwards, the average TPH of all preceding batches combined is used in the absence of on-site testing results for these final batches.

This testing suggests that a total of approximately 82,000kg of contaminants of concern (mainly as free phase hydrocarbon) have been immobilised and stabilised by the treatment.



Table 10: Treated Material Contaminant Mass Estimates

Sample Details	Date	Results	BTEX/GRO (C5 - C10) (mg/kg)	TPH (C5 - C35) (mg/kg)	Total Aromatics (C10-C35) (mg/kg)	16 EPA PAHs (mg/kg)	BaP (mg/kg)	Batch Volume (m³)	Estimated Batch Mass (kg)	Estimated Mass of Hydrocarbon (kg)
Batch 1 7 samples	17/04/15	Average	ND	669	381	71	1.8	294	514,500	344
		Min		106	33	2	0.2			
		Max		1,524	614	237	3.6			
Batch 2 5 samples	20/04/15	Average	ND	841	451	69	2.6	166	290,500	244
		Min		227	169	28	0.9			
		Max		1,563	787	116	4.2			
Batch 3 5 samples	22/04/15	Average		1,643	1,035	195	6.8	165	288,750	474
		Min	ND	1,286	760	123	4.5			
		Max		2,091	1,329	325	9.1			
Batch 4 5 samples	23/04/15	Average	ND	17,648	14,520	2,904	127.2	160	280,000	4,941
		Min		2,966	1,833	324	13.6			
		Max		39,231	34,414	6,614	309.3			
Batch 5 4 samples	24/04/15	Average	ND	1,006	811	145	5.0	161	281,750	284
		Min		792	639	110	3.8			
		Max		1,131	1,054	172	6.4			
Batch 6 No samples	27/04/15	Assumed Average		4,361				160	280,000	1,221



Sample Details	Date	Results	BTEX/GRO (C5 - C10) (mg/kg)	TPH (C5 - C35) (mg/kg)	Total Aromatics (C10-C35) (mg/kg)	16 EPA PAHs (mg/kg)	BaP (mg/kg)	Batch Volume (m ³)	Estimated Batch Mass (kg)	Estimated Mass of Hydrocarbon (kg)
Batch 7 4 samples	29/04/15	Average	ND	2,556	2,027	356	15.8	204	357,000	912
		Min		1,977	1,688	289	12.3			
		Max		3,290	2,419	417	19.2			
Batch 8 6 samples	29/04/15	Average		9,622	7,703	3,075	42.0	175	306,250	2,947
		Min	ND	2,235	1,056	166	6.6			
		Max		26,738	23,489	10,379	132.5			
Batch 9 5 samples	01/05/15	Average	ND	8,941	5,364	927	29.4	158	276,500	2,472
		Min		3,706	2,776	602	12.1			
		Max		14,487	8,286	1,356	48.2			
Batch 10 5 samples	07/05/15	Average	ND	33,691	26,883	5,608	165.4	144	252,000	8,490
		Min		4,982	1,845	259	10.0			
		Max		54,058	40,965	8,986	278.1			
Batch 11 5 samples	07/05/15	Average	ND	91,991	65,671	11,198	414.7	140	245,000	22,538
		Min		9,611	6,687	1,120	44.3			
		Max	ND	234,044	153,937	25,797	1,008.0			



Sample Details	Date	Results	BTEX/GRO (C5 - C10) (mg/kg)	TPH (C5 - C35) (mg/kg)	Total Aromatics (C10-C35) (mg/kg)	16 EPA PAHs (mg/kg)	BaP (mg/kg)	Batch Volume (m ³)	Estimated Batch Mass (kg)	Estimated Mass of Hydrocarbon (kg)
Batch 12 4 samples	14/05/15	Average	ND	19,809	11,549	1,873	63.8	212	317,000	7,349
		Min		12,599	8,844	1,456	47.5			
		Max	ND	36,904	16,715	2,642	96.5			
Batch 13 4 samples	15/05/15	Average		22,782	17,155	3,683	88.4	135	236,250	5,382
		Min		19,844	15,303	2,693	85.0			
		Max		28,248	20,650	5,159	92.6			
Batch 15 4 samples	19/05/15	Average		18,943	13,101	2,782	84.6	194	339,500	6,431
		Min		14,054	11,120	1,987	64.3			
		Max		21,244	15,710	4,009	97.3			
Batch 16 4 samples	19/05/15	Average		35,090	23,359	3,978	156.1	152	266,000	9,334
		Min		18,562	14,603	2,585	97.7			
		Max		63,860	43,890	7,476	299.2			
Batch 17 4 samples	22/05/15	Average		6,902	4,774	799	32.0	199	348,250	2,404
		Min		2,874	1,972	332	14.9			
		Max		10,561	7,350	1,220	47.4			
Batch 18 No samples	Assumed Average							60	105,000	725



Sample Details	Date	Results	BTEX/GRO (C5 - C10) (mg/kg)	TPH (C5 - C35) (mg/kg)	Total Aromatics (C10-C35) (mg/kg)	16 EPA PAHs (mg/kg)	BaP (mg/kg)	Batch Volume (m ³)	Estimated Batch Mass (kg)	Estimated Mass of Hydrocarbon (kg)
Batch 19 No samples	Assumed Average							170	297,500	2,053
Batch 20 No samples	Assumed Average							262	458,500	3,165
Totals	Average all batches			17,600	12,800	2,510				
	Min all batches			106	32.6	2.40				
	Max all batches			54,100	41,000	10,400				
	Sum all batches							3,311	5,794,250	81,710



The above data from on-site testing was obtained from samples that were tested before significant cementation / stabilisation of the treated material had occurred, with samples being completely disaggregated in an aggressive methanol/tetrahydrofuran solvent. The data is therefore considered to represent the total contaminant content of the samples taken.

In order to verify the successful solidification and stabilisation of the treated material, further samples were dispatched for water based leachate testing at a separate commercial laboratory (selected by the specialist contractor). Two types of leachate testing were performed; one on crushed / agitated samples (for rapid results, tests performed by the laboratory to BS EN 12457); and the other on monolith samples over an extended time period, to more realistically represent actual leaching conditions within the backfill (simplified tank test conducted by HBR Limited with resulting leachate tested by the commercial laboratory). The leachate results were compared directly with targets produced for the Remediation Design Report. The targets were based on a conservative assessment in the previous risk assessment reports, stipulating that there should be no long term impact on groundwater quality at the site boundary due to leaching from the backfilled, treated material within Area AC2.

Table 11 shows the results of the initial leachate testing (10:1 water to sample ratio (as per BS EN 12457)) on crushed / agitated samples, with the leachate targets also shown for comparison. Results exceeding the target values are highlighted in red and italic. These initial results gave the treatment contractor confidence that the long term tank testing results (from monolith blocks immersed in water) would meet the required targets, these results are shown in Table 12 (no exceedances).

The actual tank testing carried out by HBR was a simplified test, in accordance with their own established procedures and experience, with a single leachate sample obtained from the water surrounding the monolith sample after 64 days immersion.



The two stage leachate testing (10:1 and 64 day tank test) was done in accordance with the agreed Verification Plan (part of Remediation Strategy Report). Based on the minor exceedances for the aggressive 10:1 ratio testing and given that treated material is placed at least 600mm below ground and not subject to any weathering or disturbance, long term durability is not considered a concern. Laboratory certificates for all the leachate tests are provided in Appendix M.



Table 11: Treated Material 10:1 Leachate Test Results (BS EN 12457)

Treatment Batch No.	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8	Batch 9	Batch 10	Batch 11	Batch 12	Batch 13	Batch 14	Batch 15	Batch 16	Batch 17	Batch 18	Batch 19	Batch 20	HBR1 (Leach)	HBR2 (Leach)	HBR8 (Leach)	Target Conc
Sample Date	17/04/15	20/04/15	21/04/15	23/04/15	24/04/15	27/04/15	28/04/15	29/04/15	30/4/15	06/05/15	07/05/15	08/05/15	14/05/15	15/05/15	18/05/15	19/05/15	21/05/15	22/05/15	17/06/15	17/06/15	17/04/15	20/04/15	29/04/15	-
Total Cyanide	<10	<10	<10	<10	<10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	<10	<10	<10	<10	<40	<40	<40	36.5
Total Phenols	51	33	78	62	36	79	34	13	34	480	1300	1100	730	600	770	750	30	28	69	100	23	68	21	23400
TPH (Ali/Aro)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TPH (Aro)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	99	140	230	-
Naphthalene	32	34	64	180	13	160	35	20	70	210	690	910	970	420	270	400	110	63	60	66	<0.01	0.72	1.1	1170
Acenaphthylene	9.2	3.6	6.9	13	7.8	16	10	3.9	8.2	35	77	89	83	39	27	38	4.7	2.5	5.2	13	<0.01	< 0.01	< 0.01	-
Acenaphthene	2	1.4	4.3	21	3	5.6	5.1	2.8	12	11	14	18	16	9.9	14	10	9.1	5.5	5.3	14	<0.01	< 0.01	0.13	-
Fluorene	3.4	2	11	18	3.8	6.8	6.7	2.6	12	13	21	24	19	14	20	14	4.1	2.4	2.9	7.7	<0.01	0.14	0.06	-
Phenanthrene	3.4	2.1	11	18	3.8	7.6	11	3.5	15	16	23	26	15	13	20	14	4	2.4	3.8	9.9	<0.01	0.91	0.4	-
Anthracene	0.57	0.52	2.8	3.6	0.95	5.7	< 0.01	0.98	4.1	11	6.4	9	20	2.7	4.6	3	0.73	0.42	0.57	1.4	<0.01	0.3	0.16	4.16
Fluoranthene	0.67	0.49	2	2.3	0.75	3.2	2.2	0.75	2.3	4.9	5.2	6.2	8	1.8	3.3	2.1	0.48	0.3	0.45	1.2	<0.01	0.23	0.2	0.257
Pyrene	0.46	0.33	1.3	1.6	0.55	2.1	1.4	0.5	1.6	3.2	3.2	4.7	5.9	1.2	2.1	1.5	0.37	0.22	0.38	0.96	<0.01	0.28	0.15	-
Benzo(a)anthracene	< 0.01	< 0.01	< 0.01	0.2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	1.2	0.92	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	-
Chrysene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.93	0.92	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	-
Benzo(b)fluoranthene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.69	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Benzo(k)fluoranthene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.44	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Benzo(b)fluoranthene+ Benzo(k)fluoranthene	-	-	-	-	-	-	-	-	-	-	-	1.13	-	-	-	-	-	-	-	-	-	-	-	1.19
Benzo(a)pyrene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.69	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.01*
Indeno(1,2,3-cd)pyrene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Benzo(ghi)perylene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Indeno(1,2,3-cd)pyrene+ Benzo(ghi)perylene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0793
Dibenz(a,h)anthracene	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-
Total EPA-16 PAHs	52	44	100	260	34	200	71	35	120	300	840	1100	1100	500	360	490	130	77	78	110	<0.2	2.6	-	-
Arsenic (dissolved)	1.9	2.6	3.2	2.5	< 1.1	4.1	3.7	3	5.7	7.5	5.4	5.8	6	2.1	< 1.1	< 1.1	1.8	2.8	1.8	2.2	1.3	0.96	1.2	1400
Copper (dissolved)	1.6	6.9	4.6	4.1	3.4	14	11	7.5	7	14	8.9	13	15	2.5	3.6	4.4	14	9.8	17	26	3.7	3.5	3.2	785



Treatment Batch No.	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8	Batch 9	Batch 10	Batch 11	Batch 12	Batch 13	Batch 14	Batch 15	Batch 16	Batch 17	Batch 18	Batch 19	Batch 20	HBR1 (Leach)	HBR2 (Leach)	HBR8 (Leach)	Target Conc
Iron (dissolved)	70	70	74	44	34	180	88	120	150	130	91	130	70	14	49	51	0.1	0.11	0.042	0.041	5.8	6.8	<5.5	28100
Mercury (dissolved)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	<0.5	<0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	<0.01	<0.01	0.02	1.34
Zinc (dissolved)	2.5	1.8	4	2.8	3.7	2.3	0.9	1.1	6.5	5.7	3.4	1.5	3.5	2.8	1.2	1.7	3	2.8	14	9	<1.25	<1.25	1.54	3350

Notes: All data in ug/l. Red highlighted cells indicate exceedance of target. * - target set at laboratory analytical detection limit.



Table 12: Treated Material Tank Test Leaching Results

Sample Reference		Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8	Batch 9	Batch 10	Batch 11	Batch 12	Batch 13	Batch 14	Batch 15	Batch 16	Batch 17	Batch 18	Batch 19	Batch 20	Target Conc
Date Sampled		17/04/15	20/04/15	21/04/15	23/04/15	24/04/15	27/04/15	28/04/15	29/04/15	30/04/15	06/05/15	07/05/15	08/05/15	14/05/15	15/05/15	18/05/15	19/05/15	21/05/15	22/05/15	17/06/15	17/06/15	-
Analytical Parameter (Leachate Analysis)	Limit of detection																					
Total Cyanide	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	36.5
Total Phenols (monohydric)	10	20	21	18	34	11	29	14	11	17	36	370	500	540	310	690	480	58	45	57	69	23400
Naphthalene	0.01	85	90	160	220	13	130	200	57	90	170	870	530	580	360	810	550	170	120	140	180	1170
Acenaphthylene	0.01	3.6	2.0	13	12	1.7	7.4	17	2.4	6.9	18	65	42	47	29	52	45	9.1	4.3	13	22	-
Acenaphthene	0.01	2.0	0.77	2.9	9.8	0.99	3.8	7.5	2.3	4.9	9.3	15	7.9	10	10	11	9.4	9.2	8.1	15	22	-
Fluorene	0.01	3.0	1.0	6.0	6.6	1.1	4.0	7.9	2.1	4.0	8.5	18	11	13	11	14	13	6.7	5.8	9.6	15	-
Phenanthrene	0.01	4.2	1.3	10	8.6	1.7	5.5	11	2.8	5.7	11	20	14	15	13	18	15	9.5	7.6	13	18	-
Anthracene	0.01	0.94	0.27	2.2	1.9	0.44	1.1	2.4	0.58	1.6	3.7	3.1	3.4	3.5	2.2	3.6	2.6	2.3	1.5	2.1	2.8	4.16
Fluoranthene	0.01	0.15	0.21	0.15	0.22	0.17	0.21	0.23	0.18	0.16	0.21	0.15	0.18	0.23	0.19	0.21	0.22	0.16	0.14	0.18	0.21	0.257
Pyrene	0.01	0.55	0.19	1.2	0.90	0.32	0.73	1.1	0.39	0.74	1.2	2.4	1.5	2.1	1.7	1.7	1.7	1.1	0.84	1.3	1.9	-
Benzo(a)anthracene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-
Chrysene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-
Benzo(b)fluoranthene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.19
Benzo(k)fluoranthene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.19
Benzo(a)pyrene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Indeno(1,2,3-cd)pyrene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.0793
Dibenz(a,h)anthracene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-
Benzo(ghi)perylene	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.0793
Total EPA-16 PAHs	0.2	100	95	200	260	19	150	250	68	110	220	1000	610	670	430	910	640	210	150	200	270	-
Arsenic (dissolved)	1.1	1.1	1.1	2.1	1.1	1.1	2.7	1.7	1.2	1.1	1.1	1.6	4.4	1.1	4.5	1.6	3.3	5.4	2.3	1.1	1.1	1400
Copper (dissolved)	0.7	14	7.9	15	5.7	5.7	7.1	22	7.3	4.4	6.0	16	5.4	7.8	16	10	12	10	14	11	12	785
Iron (dissolved)	4	17	17	12	12	16	16	11	17	14	15	14	17	95	290	140	190	96	160	4	6	28100
Mercury (dissolved)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.3	0.5	1.34
Zinc (dissolved)	0.4	0.9	0.5	0.6	0.4	0.4	0.4	0.9	0.7	1.7	0.4	0.4	0.4	0.5	5.1	2.1	2.5	0.5	1.8	0.5	1.4	3350

Notes: All data in ug/l



All treated materials were used as backfill at depth within the Area AC2 excavation area; no treated material was exported from the site or deposited in any other area - this being verified by the site supervision staff who were present on the site throughout the treatment period.

4.2.3 Material Not Requiring Treatment

4.2.3.1 Concrete

The majority of the sub-surface materials within the excavation area were visibly contaminated by free phase tar or other gasworks residues, but a large amount of concrete from foundations and slabs was segregated and passed for crushing and subsequently reused without further treatment. Crushed concrete is not physically amenable to chemical testing, but all crushed materials were visually inspected and confirmed free of tar contamination prior to reuse. The fines from the concrete crushing (which included a screening element) were sampled and tested for target contaminants on-site. Due to the relatively high levels of hydrocarbon contamination found, these materials were then scheduled for treatment (mixed with other excavation arisings). Testing results are provided in Table 13.

4.2.3.2 Granular Alluvium

A small amount of natural granular alluvium material from north of the main tar tank (Grid Square A2) was segregated and stockpiled for use as the lateral containment bunds for the ex-situ treatment pad (tested as Stockpile Clean 2 – see Table 13 below). These bunds were ultimately incorporated into the final treatment batch and re-deposited into the excavation area as backfill.

Further granular alluvial materials from parts of Grid Squares D2, D3, E2 and E3 were also segregated into a temporary stockpile (Clean 4 North) and subject to testing to demonstrate that they were free of significant contamination. The results of this testing are summarised in Table 13.



4.2.3.3 Site Surface Aggregate

The only other material that was reused without passing through the ex-situ treatment was the granular gravel aggregate used as the operating surface layer prior to the start of remediation works. This material was scraped up and placed in temporary stockpiles around the excavation area prior to being re-laid as the final surface layer over the backfilled excavations. Table 13 also shows the results of the on-site testing carried out on this material (Clean 1, 3 and 4 South). In addition to the on-site testing, made ground materials recovered for reuse without treatment were sent to the laboratory for testing for the presence of asbestos fibres; the results of these tests are also shown in Table 13.

Table 13 Stockpile Testing Results

Date	Testing Details	Results (all data in mg/kg)							Material Fate
			BTEX GRO	TPH	Total Aro	16 EPA PAHs	BaP	Asbestos	
	Clean Surface Aggregate	Av	ND	226	160	13	1.3	NAD	Unrestricted reuse (without treatment)
07/04/15	(Clean 1 South)	Min		7	15	1	0.0		
	12 samples	Max		579	483	57	4.8		



Date	Testing Details	Results (all data in mg/kg)							Material Fate
			BTEX GRO	TPH	Total Aro	16 EPA PAHs	BaP	Asbestos	
10/04/15	Clean Excavation Alluvium	Av	ND	977	161	6	0.0		Incorporated into treatment stream
	Southern Stockpile / Treatment bunds (Clean 2)	Min		292	88	3	0.0		
	4 samples	Max		1,392	227	9	0.0		
14/04/15	Clean Surface Aggregate	Av	ND	607	481	96	3.6		Unrestricted reuse (without treatment)
	(Clean 3 North)	Min		301	240	44	1.6		
	6 samples	Max		874	616	128	4.7		
28-29/04/15	Clean Surface Aggregate	Av	ND	258	182	31	1.4	NAD	Unrestricted reuse (without treatment)
	(Clean 4 South / North)	Min		5	4	0	0.0		
	10 samples	Max		772	473	87	4.4		



Date	Testing Details	Results (all data in mg/kg)							Material Fate
			BTEX GRO	TPH	Total Aro	16 EPA PAHs	BaP	Asbestos	
05/05/15	Clean Excavation Alluvium	Av	ND	1,844	1,580	288	13.5		Backfill at depth only (without treatment)
	(Clean 4 North)	Min		1,508	1,434	271	12.8		
	4 samples	Max		2,155	1,799	310	14.3		
08/04/15	Dirty Excavation Spoil	Av	ND	4,759	2,586	1,058	9.7	NAD	Scheduled for treatment
	(Dirty 2 West)	Min		504	388	66	2.3		
	6 samples	Max		16,565	7,561	3,408	28.8		
15/04/15	HBR Batch 1	Av	397	3,348	2,453	832	9.2	Chrysotile	Scheduled for treatment
	Pre-treatment pad	Min	261	723	359	83	1.0		
	6 samples	Max	533	9,049	6,383	2,134	28.8		
22/04/15	HBR Batch 5	Av	ND	9,049	7,573	1,921	50.9		Scheduled for treatment
	Pre-treatment pad	Min	533	2,765	2,765	304	21.0		
	4 samples	Max	533	15,505	13,106	4,036	86.0		



Date	Testing Details	Results (all data in mg/kg)							Material Fate
			BTEX GRO	TPH	Total Aro	16 EPA PAHs	BaP	Asbestos	
21/04/15	Riddled Fines	Av	ND	2,216	1,591	384	8.0		Backfill at depth (without treatment)
	Concrete stockpile area	Min		1,694	1,234	298	5.3		
	6 samples	Max		2,638	1,939	459	11.8		
21/05/15	Crusher Fines	Av	ND	4,208	3,079	514	22.1		Incorporated into treatment Stream
	Concrete stockpile area	Min		3,393	2,794	476	20.2		
	4 samples	Max		4,717	3,339	549	23.5		

Notes: BTEX/GRO – summed volatile components; TPH – total extractable petroleum hydrocarbons; Total Aro – total aromatic hydrocarbons; BaP – benzo(a)pyrene; Av – average (mean of stated number of samples).

4.2.3.4 Radioactivity Screening

No significant radioactive contamination was found during the screening and inspection works conducted by Aurora. There was subsequently no requirement for special handling, treatment or disposal on grounds of radioactive contamination. All the diary reports and instrumental measurements are contained in the specialist contractor report, presented as Appendix D.



4.2.4 Area AC3

Water in Pond 2 and sediment in the base of the pond was sampled on a number of occasions as part of the site assessment and monitoring programme. Water entering Pond 2 from the surface water drainage outfall (draining the adjacent Flogas compound only – no connection with other remediation areas) was also sampled for comparison. Verification of the remediation is based on direct comparison of contaminant concentrations in pre-remediation (before 1st June 2015) and post-remediation samples. Compiled data for key contaminants of concern is shown in Table 14, full analytical certificates for laboratory tested samples are contained in Appendix M. No other water or sediment entry to the pond was identified at any time during the works. The monitoring locations are shown in Figure 14. Peripheral Receptor Monitoring Locations (Drawing No. A1-14890-3001).

Samples of sediment and water discharges taken during the clearance / jetting of the upstream surface water drains were tested for the same suite of contaminants and data are also presented in Table 14. Full analytical certificates for the laboratory testing are contained in Appendix M.



Table 14: Area AC3 Water and Sediment Testing Results

	Date	Temp (°C)	EC (uS/cm)	ORP (mV)	DO (%)	TOC (mg/l)	TPH / EPH (mg/l)	PAHs (ug/l)	BTEX/GRO (mg/l)	Phenols (mg/l)	Total Cyanide (mg/l)	Lead (ug/l)	Zinc (ug/l)	Ammonia (mg/l)
Main Pond – water body samples														
SS11-03-01	29/03/11		649			24	63.4	21	ND	ND	ND	ND	ND	2.60
SS11-03-01	11/12/13		469			110	1.9	2	ND	ND	ND	1.4	67	1.60
SS11-03-01	13/12/13		434			16	1.2	2.7	ND	ND	ND	0.28	49	0.27
SS11-03-01	09/01/14		369			4.5	0.26	ND	ND	ND	ND	0.79	142	0.06
SW3	05/03/15	6.6	631	172	76	3.5	0.25	<1	ND	ND	ND	ND	108	0.09
SW3	08/05/15						0.34	40	ND					
SW3	02/06/15						0.48	4	ND					
Duplicate	02/06/15						0.16	20	ND					
SW3	03/07/15	16.9	407	58	17	12	0.09	<1	ND	ND	ND	0.93	29	0.02
SW3	20/10/15	10	452	81	49.4	37	0.06	<1	ND	ND	ND	0.46	16	0.14
Drain Discharge samples														
SW3A	08/05/15						0.39	50	ND					
SW3A	02/06/15						0.15	10	ND					
Duplicate	02/06/15						0.11	10	ND					
SW3A	03/07/15	13.5	418	35	48.8	9.7	0.04	<1	ND	ND	ND	0.48	18	0.10
							TPH / EPH (mg/kg)	PAHs (mg/kg)	BTEX/GRO (mg/kg)	Phenols (mg/kg)	Total Cyanide (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Ammonia (mg/kg)
Drain Sediment samples														
SD3A	13/12/13						68	ND	ND	ND	1.8	93	1200	16
SD3A	08/05/15						31	0.50	ND					
AC3-01 Jetting residue	26/05/15						380	23	ND	ND	1.5	82	1400	15
AC3-02 Drain sediments	26/05/15						1300	110	ND	ND	3.3	170	1500	16



	Date	Temp (°C)	EC (uS/cm)	ORP (mV)	DO (%)	TOC (mg/l)	TPH / EPH (mg/l)	PAHs (ug/l)	BTEX/GRO (mg/l)	Phenols (mg/l)	Total Cyanide (mg/l)	Lead (ug/l)	Zinc (ug/l)	Ammonia (mg/l)
Pond Sediment samples														
SD3	09/01/14						2200	130	ND	ND	1.3	84	1400	6
SD3	05/03/15						150	<1	ND	ND	0.6	140	2200	8
SD3	08/05/15						177	2.30	ND					
Overflow channel sludge	02/06/15						171	3.70	ND					
New base clay														
SD3 (east)	02/06/15						10	0.11	ND					
SD3 (west)	02/06/15						3	0.11	ND					
Overflow channel new base	02/06/15						6	0.10	ND					
SD3	03/07/15						<10	<1	ND	ND	0.2	24	69	13
SD3	20/10/15						<10	<1.6	ND	ND	0.7	33	75	110

Note: ND = not detected; Blank cells indicate no testing done.



Hydrocarbon contamination in basal sediments was removed by bulk excavation. All loose sediments were scraped from the pond base, starting from the original standing water level. Excavations were continued until all recent sediments (black, sulphidic and made up largely of decaying vegetation) were cleared from the underlying, soft, plastic brown clay. A photographic record was made to demonstrate the extent of sediment removal from the pond and adjacent stretch of overflow channel.

There was no visible or olfactory evidence to suggest any significant penetration of contamination into the low permeability strata, but a number of clay samples (any sample designation SD3, dated after 01/06/15) were taken for on-site testing to confirm this. The results of the testing are also included in Table 14.

Following remediation, water and sediment samples were taken from the main pond area only and the results added to the existing monitoring data-set (see Section 4.2.6).

4.2.5 Area AC4

Water and sediment in Bedwell Brook has been sampled on a number of occasions as part of the site assessment and monitoring programme. Verification of the remediation is based on direct comparison of contaminant concentrations in pre-remediation (before 3rd June 2015) and post-remediation samples. Water entering Bedwell Brook from the surface water drainage outfalls (which are directly connected with the road drainage within Area AC2, the main site car park and other site roadways, but separate from the Flogas compound drains (see Section 4.2.4 above) has also been sampled for comparison. Compiled data for key contaminants of concern are shown in Tables 15 and 16. The monitoring locations are shown in Figure 14.

It is noted that the overflow channel from Pond 2 enters Bedwell Brook upstream of the railway embankment culvert (and therefore upstream of the main “upstream” monitoring point), but this was only observed to actively discharge any water during the Pond 2 dewatering works and is considered not to have influenced any sampling / monitoring events within the main brook itself.



A small drainage ditch originating to the immediate northeast of the Maelor Works site, discharges to Bedwell Brook just upstream of the site access road culvert, but this very small discharge was never subject to routine monitoring (other than by visual inspection) and is also considered insignificant in terms of influence on Bedwell Brook water or sediment quality.

Similarly, an old field drain discharge on the north bank of Bedwell Brook was marked on occasion by an orange brown ferruginous discharge, but flow was negligible / intermittent and sampling was not attempted.

All these discharges enter the channel upstream of the “downstream” monitoring point at the exit of the site access road culvert. No other water or sediment entry to the Bedwell Brook channel, within the remediation works area was identified at any time during the works.

Samples of sediment and water discharges (sample designation AC4) were taken during the clearance of the upstream surface water drains. These samples were tested for the established suite of contaminants and relevant data is also presented in Tables 15 and 16. Testing certificates for the samples submitted to the laboratory are provided in Appendix M.



Table 15: Area AC4 Water Testing Results

Sample ID	Date	Temp (°C)	EC (uS/cm)	ORP (mV)	DO (%)	TOC (mg/l)	TPH / EPH (mg/l)	PAHs (ug/l)	BTEX/GRO (mg/l)	Phenols (ug/l)	Total Cyanide (ug/l)	Lead (ug/l)	Zinc (ug/l)	Ammonia
Bedwell Brook – Upstream of works														
Upstream of railway culvert	13/12/13		594			11	0.21	<1	ND	ND	<40	0.21	50.4	0.26
Upstream of railway culvert	09/01/14		363			18	0.17	<1	ND	ND	<40	0.95	71	0.43
SW2	05/03/15	4.1	653	138	91.6	8.3	0.21	<1	ND	ND	<40	0.27	12.6	0.07
SW2	25/03/15	6.5	836	74	87.2									
SW2	02/06/15						0.07	7						
SW2	03/06/15						0.11	10						
SW2	02/07/15	14.7	597	110	59	6.1	<0.01	<1	ND	ND	<40	2.7	15	0.05
SW2	20/10/15	9.3	643	118	80.5	70	0.04	<1	ND	ND	<40	1.5	15	<0.02
Main Water Body – Downstream of outfalls														
SS11-02-03	10/12/13		503			13	0.13	<1	ND	ND	<40	0.38	10	0.45
SS11-02-03	10/01/14		564			13	0.43	3	ND	ND	<40	0.56	155	1.1
SS11-01-1	29/03/11		621			7.4	0.03	<1	ND	ND	<20	<0.1	3	<0.1
SS11-01-1	10/12/13		514			6.7	0.13	<1	ND	ND	<40	0.1	16	0.48
SS11-01-1	09/01/14		385			3.4	0.2	<1	ND	ND	<40	0.47	37.2	0.06
Main channel	06/05/15						2.4	420	ND					
At SW4 outfall	02/06/15						0.64	4	ND					
BB1	03/06/15						0.86	110	ND					
BB2	03/06/15						1.5	70	ND					
BB3	03/06/15						0.88	110	ND					
SW10	20/10/15	10.3	637	96	77.2	27	0.06	<1	ND	ND	<40	1.4	8.2	<0.02
Main Water Body – Downstream of works														
SS11-08-01	29/03/11		631			7.4	0.03	<1	ND	ND	<20	<0.1	2	<0.1
SS11-08-01	10/12/13		597			11	0.14	<1	ND	ND	<40	0.69	62	0.17
SS11-08-01	09/01/14		343			20	0.55	<1	ND	ND	<40	3.9	65.5	0.16
SW1	05/03/15	4.1	634	186	88.4	7.9	0.16	<1	ND	ND	<40	0.3	15.4	0.04
SW1	25/03/15	6	952	51	81.6	14	1.4	1.3	ND	4.8	<40	0.78	3.38	2.2

Sample ID	Date	Temp (°C)	EC (uS/cm)	ORP (mV)	DO (%)	TOC (mg/l)	TPH / EPH (mg/l)	PAHs (ug/l)	BTEX/GRO (mg/l)	Phenols (ug/l)	Total Cyanide (ug/l)	Lead (ug/l)	Zinc (ug/l)	Ammonia
SW1	26/03/15					12	0.41	<1	ND	1.2	<40	0.32	20.4	0.19
SW1	06/05/15						0.73	80						
At access road entrance	02/06/15						0.92	8	ND					
BB4	04/06/15						2.3	270	ND					
SW1	02/07/15	15.3	469	100	73.5	1.8	<0.01	<1	ND	ND	<40	1.7	7.82	0.21
SW1	20/10/15	9.8	648	111	74.4	69	0.07	<1	ND	ND	<40	1.7	17.0	<0.02
Surface Water Drain Outfalls														
SW4	05/03/15	7.6	377	-46	94	2.3	0.36	1.5	ND	ND	<40	<0.1	7.49	0.46
SW4	02/06/15						5	60	ND					
SW4	02/07/15	13.4	322	-14	92									
SW4	20/10/15	13.1	502	63	80.3	51	0.28	<1	ND	ND	<40	1.1	13.0	3.60
SW5	05/03/15	9.1	1146	-38	6.7									
SW5	02/07/15	10.9	996	-53	81.9									
AC4-03	27/05/15					66	1.1	14	ND	6.6	<40	<0.1	43.9	0.52
AC4-04	27/05/15					19	0.07	<1	ND	1	52	<0.1	33.2	2.7

Notes: ND = not detected, blank cells indicate no testing done.



Complete excavation of the sediments was undertaken within the concrete lined section of the channel at, and immediately downstream of, the main surface water drain outfall (between the two temporary dams installed for the channel dewatering). Access and plant restrictions prevented the complete removal of loose sediments from the channel between the downstream dewatering dam / crossing point and the site access road culvert.

After an initial scrape of loose sediments from the whole channel section, it was observed that some sediment still released visible LNAPL hydrocarbon sheens and globules (either on physical disturbance or on standing undisturbed for a few hours). A second round of excavation was undertaken, concentrating on areas where visibly impacted sediment was concentrated, and continuing until no more hydrocarbon release was visible. This resulted in the channel section being in the form of a series of relatively flat sections (where most sediment was removed), with short lengths of slightly steeper bed gradients between, this being compliant with the ponds and riffles profile that had been proposed on the OWC consent application. A photographic record was made of the dewatered channel after sediment removal and again after flow had been restored (see Appendix E).

Samples of the exposed residual sediment in the base of the dewatered channel, following excavation, were taken at 10m intervals, measured downstream from the end of the concrete lined section, as far as the pool immediately upstream of the access road culvert entrance. Samples were noted to be free of any visible free phase hydrocarbon contamination. Each sample was subjected to on-site testing for the established suite of hydrocarbon contaminants. The results of this on-site testing are also shown in Table 16.

Following remediation, water and sediment samples continued to be taken from the established channel and surface water drain outfall locations. The results were added to the existing monitoring data-set (see Section 4.2.6).



Table 16: Area AC4 Sediment Testing Results

Sample ID	Date	TPH (mg/kg)	PAH (mg/kg)	BTEX (mg/kg)	Phenol (mg/kg)	Total Cyanide (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Ammonia (mg/kg)
Upstream of outfalls									
Upstream of railway culvert	13/12/13	<10	<1		ND	0.2	440	240	52
SD2	10/12/13	190	10		ND	0.7	690	210	6
	09/01/14	1000	71		ND	0.9	630	280	48
	09/01/14	65	6.3		ND	0.2	740	260	13
SD2	05/03/15	120	11	ND	ND	0.5	630	310	8.8
SD2	06/05/15	271	35.8	ND					
SD2	03/07/15	<10	<1	ND	ND	0.9	340	300	16
SD2	20/10/15	<10	<1	ND	ND	0.5	700	310	14
Downstream of outfalls									
SD4	10/12/13	2900	340	ND	ND	1.5	660	260	18
SD4	09/01/14	190	14	ND	ND	0.6	980	270	21
AC4-01	27/05/15	7600	16	ND	ND	2.3	160	270	45
AC4-02	27/05/15	220000	40000	60	1	<0.1	24	79	5.9



Sample ID	Date	TPH (mg/kg)	PAH (mg/kg)	BTEX (mg/kg)	Phenol (mg/kg)	Total Cyanide (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Ammonia (mg/kg)
SD5	05/03/15	20	<1	ND	ND	20	18	77	8.4
Downstream of works									
SD1	10/12/13	<10	<1	ND	ND	0.6	1800	300	6.2
SD1	09/01/14	290	14	ND	ND	1.5	400	170	31
SD1	05/03/15	360	56	ND	ND	1.0	1700	400	9
SD1	06/05/15	100	1.5	ND					
SD1	03/07/15	530	38	ND	ND	7.5	630	410	21
SD1	20/10/15	120	23	0.08	ND	0.2	420	240	21
Sediment Exposed by excavations									
B1 pool below crossing point dam	03/06/15	569	33.2	ND					
B2 - 7m downstream of B1	03/06/15	102	11.5	ND					
B3 - 14m downstream of B1	03/06/15	154	16	ND					
B4 - 24m downstream of B1	03/06/15	179	25.3	ND					
B5 - 35m downstream of B1	03/06/15	903	154	ND					



Sample ID	Date	TPH (mg/kg)	PAH (mg/kg)	BTEX (mg/kg)	Phenol (mg/kg)	Total Cyanide (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Ammonia (mg/kg)
B6 - 45m downstream of B1	03/06/15	540	57.4	ND					
B7 - 55m downstream of B1	03/06/15	1559	147	ND					
B8 - 65m downstream of B1	03/06/15	382	39	ND					
B9 - Access road culvert pool	03/06/15	604	62	ND					



4.2.6 Peripheral Receptor Monitoring

Monitoring of water and sediment quality in receptors on the periphery of the remediation works, was conducted throughout the active site period, as a continuation of monitoring that had been undertaken as part of the site investigation and assessment work dating back to 1999. Two additional rounds of monitoring were conducted one month and four months after the completion of the active remediation works. The monitoring locations are shown in Figure 14.

Monitoring was split into three categories:

- Surface water and sediment within the site surface water drainage and Bedwell Brook (including Pond 2);
- Groundwater quality in Area AC1, including the water collected by the French Drain along the north western site boundary;
- Groundwater quality within Area AC2 around the former gas processing facilities.

Tables 14 to 16 show the results of surface water and sediment testing for selected key contaminants over the period spanning the site investigation and remediation phases of the works and beyond (up to October 2015). Table 17 shows the results of groundwater monitoring (in areas peripheral to the remediation works) for the same key contaminants over the same time period.

The data supports the other verification information described in earlier sections as follows:

- Area AC1 - No significant deterioration or change in water quality at the external collection point (French Drain / SW6) or peripheral monitoring boreholes for Area AC1. A continuation of no identifiable impacts on external groundwater or surface water (River Clywedog) receptors.



- Area AC2 – Dramatic improvements in groundwater quality in the borehole beneath the retained garage building, due to the removal of major free phase contamination in the made ground immediately to the south (up hydraulic gradient). No significant change in groundwater quality in the vicinity of the Training Centre building, which does not receive significant groundwater flow from remediation areas and is adjacent to a roadway with known residual contamination beneath. Contamination in this area has previously been assessed as not requiring remediation in its own right (see IKM REP005 for details).
- Area AC3 – Confirmation of no routine inflow of contamination from the surface water drain (the only input to Pond 2. Confirmation of good water quality and absence of contaminated sediments within the Pond 2 waterbody.

It is noted that Pond 2 remains potentially vulnerable to any future spill or leak of polluting material entering the surface water drainage in the operational site area to the west (Flogas Compound).

- Area AC4 – Improvements in the quality of water entering Bedwell Brook from the site surface water outfalls following drain clearance and the remediation work in Area AC2. Confirmation of no significant changes to water or sediment quality upstream or downstream of the Area AC4 remediation area. It is noted that Bedwell Brook remains potentially vulnerable to any future spill or leak of polluting material entering the surface water drainage in the main operational site areas to the north and west (WWU operational areas and site car parks).



Table 17: Peripheral Receptor Groundwater Monitoring Results

Location	Date	Temp (°C)	EC (uS/cm)	ORP (mV)	DO (%)	TOC (mg/l)	TPH / EPH (mg/l)	PAHs (ug/l)	BTEX/GRO (ug/l)	Phenols (ug/l)	Total Cyanide (ug/l)	Lead (ug/l)	Zinc (ug/l)	Ammonia (mg/l)
Area AC1 Boreholes														
MW11-02	28/07/11		3,420			45	0.03	2	ND	31.3	3980	1	4	10
MW11-02	10/01/14		1,080			28	0.49	<1	ND	ND	1100	9.7	30.9	5
MW11-02	06/03/15	8.5	2,266	-53		350	0.75	0.5	ND	ND	750	0.26	76.2	2
MW11-02	09/04/15	10.2	2,470	-26	2.9		46.4	ND	ND					
MW11-02	16/04/15	9	2,533	-47	2.3		26.8	520	ND					
MW11-02	23/04/15	12.2	2,589	-105	2.9		40.7	2800	ND					
MW11-02	30/04/15	9.1	2,650	-73	2.7		28.4	350	ND					
MW11-02	07/05/15	11.2	2,436	-60	1.0		28.9	3200						
MW11-02	15/05/15	9.8	2,311	-81	29.1		2.6	ND						
MW11-02	03/07/15		2,420			250	0.41	0.38	ND	ND	850	1.4	42	4
MW99-104	06/04/99		2,330			23	0.35	<10	ND	ND	300	<30	20	102
MW99-104	28/07/11		1,620			14	<0.01	<1	ND	ND	430	<1	<1	64
MW99-104	11/12/13		1,550			31	0.6	<1	ND	ND	310	0.73	27.1	70
MW99-104	10/01/14		1,800			24	0.37	<1	ND	ND	390	0.39	41.1	49
MW99-104	06/03/15	11.5	1,650	-97		37	0.26	<1	ND	ND	480	<0.1	3.9	55
MW99-104	25/03/15	9.8	1,596	-92	37.5		3.3	40	ND					
MW99-104	02/04/15	10	1,465	-76	34.2		3.6	130	ND					
MW99-104	09/04/15	10.9	1,634	-89	1.1		6.1	50	ND					
MW99-104	16/04/15	10.6	1,604	-75	1.3		0.31	ND	ND					
MW99-104	23/04/15	12.1	1,574	-99	2.2		3.9	60	ND					
MW99-104	30/04/15	10.2	1,597	-99	2.6		0.72	80	ND					
MW99-104	07/05/15	11.2	1,450	-91	1.5		0.64	ND	ND					
MW99-104	15/05/15	10.1	1,466	-86	29.6		0.74	20	ND					
MW99-104	03/07/15	14.3	1,362	-80	36.4	6	0.22	0.75	ND	8.2	250	<0.1	27.9	57
MW99-104	19/10/15	12.8	1,471	-73	32.2	150	0.09	<0.2	ND	<0.1	<40	<0.1	5.2	71
MW99-106	06/04/99		2,400			27	0.65	50	ND	400	300	<30	10	182



Location	Date	Temp (°C)	EC (uS/cm)	ORP (mV)	DO (%)	TOC (mg/l)	TPH / EPH (mg/l)	PAHs (ug/l)	BTEX/GRO (ug/l)	Phenols (ug/l)	Total Cyanide (ug/l)	Lead (ug/l)	Zinc (ug/l)	Ammonia (mg/l)
MW99-106	28/07/11		2,350			21	0.28	12.5	ND	892	320	<1	<1	164
MW99-106	12/12/13		1,600			33	2.3	0.22	ND	140	130	2.7	28.9	120
MW99-106	10/01/14		1,670			31	3.7	12	15.6	210	140	0.42	22.2	74
MW99-106	03/07/15	14.5	1,191	-34	25.0	16	0.08	<0.1	ND	ND	430	0.11	13.2	53
MW99-106	19/10/15	12.9	1,062	-45	40.4	110	0.04	<0.2	2.1	ND	<40	0.12	15.0	76
French Drain														
SS11-07-01	29/03/11		1,500			12	0.02	<0.1	ND	ND	820	<0.1	9	21
SS11-07-01	09/12/13		1,400			18	0.55	<0.1	ND	ND	250	0.26	37.3	14
SS11-07-01	09/01/14		1,190			31	0.39	0.24	ND	ND	240	0.58	55.1	3
SW6	03/05/15	5.5	1,074	123	52.0									
SW6	03/07/15	15.4	1,178	165	20.0	25	0.05	<0.1	ND		350	0.17	17.8	45
SW6	20/10/15					100	0.12	1.5	ND	ND	<40	0.12	18.0	39
Training Centre Boreholes														
TC1	23/03/15	9.2	606	18	15.7	210	2.3	<0.1	ND	ND	70	0.58	6.14	<0.1
MW99-205	24/03/15	7.5	427	-220	23.9	47	16	590	3252	ND	130	0.65	35.6	15
MW99-205	03/07/15	13.4	399	-132	31.9	200	4	57	1167	2200	46	0.75	10.3	13
MW99-205	20/10/15	14.2	356	-84	39.5	28	5	67	1540	ND	<40	0.43	6.6	18
Garage Borehole														
BH26B	06/03/15	9.3	663	-146		440	9.8	1200	5380	2900	<40	0.1	39.5	14
BH26B	03/07/15	14.9	796	-59	30.2	60	0.89	13	256	85	<40	1.0	11.6	4
BH26B	20/10/15	14.2	473	14	35.0	84	0.87	0.14	ND	ND	<40	0.94	17.0	6

ND = Not detected



4.3 Volumes of Material Removed and Treated

4.3.1 Area AC1

The total volume of groundwater removed, treated and discharged from this area is calculated as 2,148m³. Water abstraction was actively managed to as close to this level as possible, in order to comply with regulatory limits on the unlicensed abstraction of groundwater the water abstraction licence application was not determined by NRW, before the cessation of site works. It is also noted that local aquifer variability resulted in lower than anticipated productivity, with one abstraction well yielding no sustainable flow. The volume of groundwater removed is therefore considered to represent the maximum possible volume under the circumstances pertaining to the active remediation works.

4.3.2 Area AC2

The total volume of material excavated from Area AC2 was 5,083m³. A total of 3,158m³ of this material was scheduled for ex-situ treatment, with the remainder being recovered for direct reuse without treatment (980m³) and reuse after crushing and screening (945m³). All treated / crushed materials were backfilled within the excavation zone, no excavated materials were removed off-site for disposal, apart from a few loads of separately segregated metals, which were exported off-site for recycling at an appropriately licensed facility (see Appendix H for details).

The lower than anticipated volume of treated materials arose due to the absence of significantly tar impacted natural strata to the north and west of the former main tar tank and a much larger than expected amount of buried concrete within the excavation areas (which did not require treatment prior to reuse).

An estimated total (calculated from measured total sewer discharge – estimated groundwater abstraction) of some 863m³ of water collecting within the temporary open excavation areas, was transferred by surface pumping, to the on-site WTF for treatment and discharge to sewer.



4.3.3 Area AC3

The total volume of sediment excavated from the pond is estimated at 100m³. The total length of cleared surface water drains was 302m. All sediment arisings were incorporated into the ex-situ treatment batches (Batch 19 and 20).

4.3.4 Area AC4

The total volume of sediment excavated from the channel is estimated at 53m³. The total length of cleared surface water drains was 523m. All sediment arisings were incorporated into the ex-situ treatment batches (Batch 19 and 20).

4.4 Stockpiles Management and Stockpile Sampling

Temporary stockpiling was used within the Area AC2 excavation area for materials awaiting transfer to the ex-situ treatment area. Separate stockpiles were created daily for concrete and other oversize material and material designated directly for treatment. No movement of stockpiled material occurred without checking between the site foreman and supervisors as to the nature of the material and its intended destination.

4.4.1 Stockpiles for direct reuse

A separate stockpile was created for the clean sandy clayey aggregate (quarry scalplings) that formed the open storage surface layer prior to the commencements of the remediation works. This stockpile was formed initially in the far south of the excavation area and designated “Clean 1” for on-site testing purposes. Once excavations reached this part of the site, the stockpile was moved and placed on top of the undisturbed, backfilled tar tank in the north of Area AC2, with more surface aggregate from the southwestern sector of the remediation area added to it. The new stockpile was designated “Clean 3 North” and subject to re-sampling and testing.

Undisturbed and unimpacted sands and gravels from a small area in the far west of the excavation area was also formed into a stockpile, directly adjacent to and extending south from Clean 3 (the materials were visually easily distinguishable). This stockpile was also subject to sampling and testing and was designated “Clean 4 North / South”.



Concrete and oversize material transferred to the ex-situ treatment area was placed in a single stockpile awaiting processing. Due to space constraints, this stockpile was initially processed by screening (riddling) alone, with a new stockpile of fines being formed in the process. This stockpile was retained within the ex-situ treatment compound and subject to sampling and testing (designated as Riddled Fines). Following confirmation that concentrations of hydrocarbon contamination were minimal, this material was transferred back to Area AC2 for use as backfill.

4.4.2 Stockpiles of Material for Treatment

Any stockpiled visibly impacted materials within Area AC2 were transferred as quickly as possible directly into the ex-situ treatment compound where they were formed into treatment pads ready for mixing. Each treatment pad was designated with a sequential number (Batches 1 to 20 in total), with all surveying, treatment reagent additions and sampling being referenced to individual Batch Numbers. Treated material from each batch was lifted and transferred directly back into Area AC2 for use as backfill. The treated material (a soft loose brown homogeneous clayey soil) was visibly easily differentiated from any other material types being handled within the site.

Two separate stockpile were formed during the final clearance of the concrete stockpile within the ex-situ treatment area. This clearance was conducted using a combined crusher / screen to produce a coarse aggregate for direct reuse (testing not feasible / appropriate), along with a separate stockpile of crusher fines that was subject to sampling and testing. As a result of the relatively high levels of hydrocarbon contamination detected (compared against known clean materials), this stockpile was scheduled for incorporation into the adjacent ex-situ treatment pads (mixed with materials transferred directly from Area AC2).



4.5 Water Treatment and Disposal

All water arisings within the excavation works and groundwater abstraction area were transferred directly to the licensed on-site WTF within Area AC1. The WTF had a discharge consent from Dwr Cymru (copy included in Appendix L) and all effluent from the site was discharged to local foul sewer under the terms of that consent (total volume measured as 3,011m³, see Table 5 for details).

The WTF was operated and maintained throughout the site works period by the specialist contractor, Geo², who provided regular update reports and a final decommissioning report following removal of the WTF from site. A copy of the consent, sampling regime and the results of testing on effluent samples are contained in the Geo² site reports provided as Appendix L.

Residual water arisings from Areas AC3 and AC4 were transferred with excavated sediments to the ex-situ treatment area and incorporated into the solidification /stabilisation process.

4.6 Backfill of Excavations

Backfilling of the excavations within Area AC2 has previously been described in Sections 4.1.2 and 4.2.2.

Backfill exclusively utilised treated and recovered material from the initial Area AC2 excavations and additional treated pond and brook channel sediments from areas AC3 and AC4 (total volume only 153m³). No imported material was used for any backfill, except the Area AC2 central roadway re-instatement, which required the import of new tarmacadam surfacing specifically for that purpose.

All treated material was placed a minimum of 200mm below the final site surface and provided with a warning layer (orange plastic mesh) between the treated material and overlying final surface materials, to indicate the presence of stabilised / solidified materials (see Section 4.7 below). Backfill areas are all fully recorded on site survey plans and can be traced to individual treatment batch records if necessary.



All treated material was subject to close control and testing to demonstrate that it was suitable for use as backfill above and below the local groundwater table, although actual water permeability is anticipated to be very low and all backfill areas are provided with high permeability, granular layers to encourage flow through of infiltration and shallow groundwater and thereby minimise percolation through / leaching from the backfill. Details of the verification of the treatment process have previously been described in Section 4.2.2.3 of this report.

The final surface for Area AC2 comprises a 200mm layer of aggregate, graded to a nominal radial fall (to surrounding and transecting roadways) and compacted using a self-propelled vibrating roller. Final surface material was sourced from the original site surface aggregate that had been stockpiled separately during the works, along with crushed clean concrete and brickwork from the processed stockpile within the ex-situ treatment area (see Section 4.2.3).

4.7 Retained / Residual Contamination

As specified earlier in this report (Section 3.8.1), limited areas of untreated (residual) contamination have been identified around the periphery of Area AC2. Details are provided on Figure 10. This shows limited occurrences of contamination beneath active site roadways, within active underground service corridors and beneath occupied buildings. These occurrences do not constrain the current use of the site, but need to be re-assessed / considered in the event that a change of site use or new development is proposed.

The presence of contamination should also be borne in mind in the event that the ground needs to be disturbed in the vicinity of the recorded residual occurrences for the purposes of underground services or drainage maintenance (or new installation thereof).

Similarly, the presence of treated materials (that contain the solidified / stabilised tars, hydrocarbons and other gasworks residues) as backfill within the former Area AC2 excavations does not constrain the current use of the site area as general open storage, but does need to be considered if that ground is to be disturbed, or a new development / site use is being proposed. Details of the chemical composition and leaching behaviour of the treated materials are provided in Section 4.2.2.3 of this report.



Further detailed descriptions and testing data for contamination beneath occupied buildings are contained in historical site investigation reports (IKM REP005 and REP006).

4.8 Geotechnical Proving of Ground Conditions

Geotechnical testing was conducted on natural strata (clay) at the base of the excavation areas in Area AC2 and on backfill surfaces (compacted treated material), prior to final completion of the reinstatement.

Geotechnical testing locations are shown on Figure 13. Test result certificates are provided in Appendix N. Test results demonstrate the typical bearing strength of the tested materials (natural clay at depth and the treated material backfill), although it is noted that testing was conducted before the cementation reactions within the treated materials had had time to fully complete. The strength of the treated materials would therefore be expected to gradually increase over a period of time as these reactions move to completion, in a manner similar to other concrete or other cement containing materials.

All excavation areas have been re-instated to a standard appropriate for general open storage use and vehicle tracking. No further testing is considered necessary at this time.

The central roadway that transects area AC2 from east to west was removed during excavation work and subsequently replaced along the same alignment to appropriate highway standards.

4.9 Quality Control Procedures Adopted

4.9.1 Area AC1

QC for the water treatment processes was carried out by way of VOC monitoring at key points within the treatment sequence (initial settlement tank, after filtration and after passing through the activated carbon treatment media). Performance was also monitored by way of effluent testing for key contaminants.



After several weeks of operation, low levels of breakthrough of VOCs were noted at the outlet from the first of the two activated carbon filter towers and this was subsequently was monitored carefully during the regular maintenance visits by the WTF contractor. No detectable breakthrough of VOC beyond the second activated carbon filter tower was detected at any time and no exceedances of the discharge consent conditions were detected in effluent samples tested. The results of the QC and effluent monitoring are contained in the Geo² site update reports, contained in Appendix L.

4.9.2 Ex-situ Treatment Process

QC for the solidification / stabilisation process was conducted by the specialist contractor carrying out the work (HBR). Solidification / stabilisation treatment was conducted on a batch basis, with each batch being prepared as a roughly rectangular pad of graded and levelled materials placed within perimeter bunds and surveyed to calculate the volumes of material being treated. Any oversize objects were hand-picked from the treatment pad at this time and placed in the adjacent concrete stockpile.

Each batch was then subject to carefully controlled treatment agent (lime and ground granulated blast furnace slag) and water addition, with full depth mixing of the treatment pad materials between each addition. Quantities and methodologies were based on previously conducted treatment trials and experience from preceding site batches.

The use of the Wirtgen rotavation machine allowed full control over the mixing process and accurate measurement of reagent additions. Due to the dramatic visible difference in appearance between treated and untreated materials, visual inspection of the treatment pad allowed confirmation of efficient and complete mixing, with no patches or clumps of black impacted material remaining.



Records were kept of reagent and water addition to each batch and samples (2 representative samples from each batch of between 60-260m³, average volume 160m³) were taken for subsequent leachate testing – crushed sample and monolith - at a commercial accredited laboratory. Materials were retained on the treatment pad until the contractor was satisfied that full mixing and appropriate reagent addition was complete. Treated material was then released for transfer back to the excavation area for use as backfill, usually within 24 hours of treatment and before the cementation reactions (involving the soil materials, GGBS and lime) were fully complete. Treated material was therefore placed as backfill before it became hardened / difficult to handle.

Verification testing results for the treatment process are described in detail in Section 4.2.2.3.

Backfilled treated material was also subject to geotechnical strength testing as described in previous sections (Section 4.8 and Appendix N).

4.9.3 Site Testing

On-site testing was established during the site works to allow analytical data to be provided in quantity and rapidly as a basis or support for, the assessment of remediation actions and impacts. Given the nature of the established contaminants of concern, site testing facilities were provided that could undertake analysis for hydrocarbons in soil and water (including coal tar indicators – total aromatic hydrocarbons and PAH) and instrumental measurement of gross water quality parameters (pH, electrical conductivity, redox potential, dissolved oxygen and temperature).

The site testing for hydrocarbons was conducted using a purpose designed UV Fluorescence instrument (QED analyser), subject to daily internal calibration and performance checks (which have to be passed before the instrument software will allow the user to proceed with actual analysis).



Prior to the commencement of the main remediation works, the on-site testing procedures were developed in conjunction with advice and assistance from the instrument supplier (QROS). The solvent extraction process used in conjunction with the UV Fluorescence instrument was subject to a series of performance checks to determine the effects of different site variables (extraction time, agitation methods, sample disaggregation and settling times and centrifuging impacts). Based on these tests, a standard routine for the preparation of samples was developed and used throughout the site works. It is noted that the QED soils analysis is based on a solvent extract of a small sub-sample of the original soil (or other solid) sample. The solvent used is a bespoke mixture of methanol (90%) and tetrahydrofuran (10%), which has been developed by QROS to maximise extraction performance in environmental samples (including water saturated, clayey soils that may not be so conducive to water immiscible organic solvent extraction).

In addition, for tests that were being used as the basis for verification, duplicate samples were dispatched to the commercial laboratory that was undertaking testing for the wider remediation works project (DETS). The laboratory cross check was conducted at a rate of 10% of samples tested by on-site testing and allowed a correlation to be established between on-site testing and the laboratory testing. It is evident from the laboratory cross check work that the on-site testing produced significantly higher aromatic TPH / PAH concentrations than reported by the laboratory. After consideration of the nature of the samples / sub-samples being tested and the differences in extraction conditions and solvents used, it is concluded that the differences between laboratory and site testing results are most likely due to the more effective extraction process and larger sub-samples utilised by the site testing procedure.. This positive bias for on-site testing was considered to be acceptable in that it reduced the possibility of any false negative data being incorporated into site decision making or any subsequent verification assessment.



Results from the on-site procedural testing work are provided in Appendix P. Table 18 presents the results from the laboratory cross check sample testing, with the on-site testing results alongside for comparison. Some of these data emphasise the heterogeneity of the excavated impacted made ground and soils being treated (the range of concentrations reported from multiple individual samples from one stockpile or treatment batch), as well as the likely differences in extraction efficiency.

Table 18. Laboratory and Site Testing Comparison Data

Sample ID	Date Tested	TPH / EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
SD1	05/03/15	360		56		5.4			
Downstream Sed	06/05/15		100		1.5		0.06		<2.1
SD1	03/07/15	530		38		4.2		<0.01	
SD2	05/03/15	120		11		1.1			
Upstream Sed	06/05/15		271		36		0.9		<2.1
SD2	03/07/15	<10		<1.6		<0.1		<0.01	
SD3	05/03/15	150		<1.6		<0.1			
SW3 Sed	08/05/15		177		2.3		0.05		<1.9
	03/07/15	<10		<1.6		<0.1		<0.01	
AC2 Clean	23/03/15	540		1.7		<0.1		<0.01	
Clean 1A	23/03/15		567		57		4.8		<32.5
Clean 1B	23/03/15		219		21		1.9		<66
Clean 1C	23/03/15		497		9		0.66		<66
Clean 1D	23/03/15		146		5		<0.65		<66
Clean 1E	23/03/15		579		11		0.65		<66



Sample ID	Date Tested	TPH / EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
Clean 1F	23/03/15		236		9		0.66		<66
AC2 Dirty	08/04/15	160		2.6		<0.1		0.08	
Dirty 1A	08/04/15		504		66		2.3		<32
Dirty 1B	08/04/15		16,570		3,410		29		<2,000
Dirty 1C	08/04/15		2,780		1,204		7.9		<645
Dirty 1D	08/04/15		4,270		1,113		5.6		<575
Dirty 1E	08/04/15		2,430		421		9.5		<550
Dirty 1F	08/04/15		2,000		136		4.3		<65
HBR1	17/04/15	510		34		0.7		2.39	
Batch 1A	15/04/15		723		168		0.96		<66
Batch 1B	15/04/15		2,300		899		6.2		<66
Batch 1C	15/04/15		1,430		83		2.7		<66
Batch 1D	15/04/15		1,340		158		1.3		<66
Batch 1E	15/04/15		5,240		2,134		15		<2,670
Batch 1F	15/04/15		9,050		1,550		29		<2,670
Grid1 Comp1	21/04/15	13		<1.6		<0.1		0.01	
Grid1 Comp2	21/04/15	<10		<1.6		<0.1		<0.01	
Grid Average 1-10	21/04/15		128		3.5		0.12		<2.1
Grid Average 11-20	21/04/15		13		1.1		0.03		<2.1



Sample ID	Date Tested	TPH / EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
EE4S3	14/04/15	19		<1.6		<0.1		<0.01	
EE4 S2	14/04/15		6		0.11		<0.02		<2.1
EE4 S2 Repeat	14/04/15		6		0.12		<0.02		<2.1
CLEAN 4-COMP	29/04/15	150		12		0.5		0.07	
Clean 4 A	29/04/15		217		29.8		1.2		<2.1
Clean 4B	29/04/15		103		3.1		0.07		<2.1
Clean 4C	29/04/15		38		8		0.34		<2.1
Clean 4D	29/04/15		51		7.8		0.24		<2.1
Clean 4E	29/04/15		5		0.2		0.02		<2.1
C1-C2-COMP	29/04/15	<10		<1.6		<0.1		<0.01	
C1-C2 Average 1-6	27/04/15		25		0.09		0.07		<2.1
C1-C2 Average 7-12	27/04/15		32		0.48		0.02		<2.1
BATCH 8-COMP	29/04/15	570		63		2		2.24	
Batch 8 Average	07/05/15		9,621		3,075		42		<260
F2-COMP	05/05/15	<10		<1.6		<0.1		0.91	
F2 Average	06/05/15		281		1.64		0.02		<2.2
F2W2	22/05/15	<10		<1.6		<0.1		<0.01	
F2W1	06/05/15		9		0.09		<0.02		<2.2



Sample ID	Date Tested	TPH / EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
F2W2	06/05/15		14		1.6		<0.02		<2.2
H3 COMP	22/05/15	<10		<1.6		<0.1		0.28	
H3 Max	13/05/15		1,555		48.3		1.3		<76
H3 Average	13/05/15		350		6.8		0.21		<2.5
G1 S22	22/05/15	<10		<1.6		<0.1		0.63	
G2 Max	07/05/15		869		31		0.09		<2.1
G2 Average	07/05/15		427		10.8		0.04		<2.1
F2G2S3	22/05/15	1,900		190		12		0.17	
G2F2S3	05/05/15		1,718		271		14.3		<58
H7W1	22/05/15	5,800		180		<0.1		4.59	
H6W10	22/05/15		10,896		406		0.44		<51
H6G6 COMP	22/05/15	<10		<1.6		<0.1		0.41	
7 Average	22/05/15		960		4.1		0.01		<2.1

Direct duplicate sample data has been extracted from the results (laboratory duplicates were blind and not labelled as such) and is presented in Table 19 below.

Table 19: Duplicate Sample Data Comparison

Sample Type	Sample ID	Results Reported							
		TPH/EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
Unimpacted natural alluvium stockpile	AC2 Clean Clean 1 (average)	540	374	1.7	19	<0.1	1.6	<0.01	<66



Sample Type	Sample ID	Results Reported							
		TPH/EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
Visibly impacted temporary stockpile	AC2 Dirty Dirty 1 (average)	160	4,759	2.6	1,058	<0.1	9.8	0.08	<65
HBR Batch 1	HBR1 Batch 1 (average)	510	3,347	34	832	0.7	9.2	2.39	<66
Base clay	Grid1 Comp1 Grid 1-10 (average)	13	128	<1.6	3.5	<0.1	0.12	0.01	<2.1
Base clay	Grid2 Comp2 Grid 11-20 (average)	<10	13	<1.6	1.1	<0.1	0.03	<0.01	<2.1
Clean stockpile	Clean 4 Comp Clean 4 (average)	150	83	12	9.8	0.5	0.37	0.07	<2.1
Base Clay	C1-C2 Comp C1-C2 (average)	<10	29	<1.6	0.29	<0.1	0.05	<0.01	<2.1
HBR Batch 8	Batch 8 Comp Batch 8 (average)	570	9,621	63	3,075	2	42	2.24	<260
Base Clay	F2 Comp F2 (average)	<10	281	<1.6	1.64	<0.1	0.02	0.91	<2.2
Wall alluvium	F2W2 F2W2	<10	13.5	<1.6	1.6	<0.1	0.04	<0.01	<2.3
Base Clay	H3 Comp H3 (average)	<10	350	<1.6	6.8	<0.1	0.21	<0.01	<2.1



Sample Type	Sample ID	Results Reported							
		TPH/EPH		PAH (US EPA 16)		BaP		BTEX	
		DETS	QED	DETS	QED	DETS	QED	DETS	QED
Base Clay	F2G2S3 G2F2S3	1,900	1,718	190	271	12	14.3	0.17	<58
Base Clay	H6G6 Comp H7 (average)	<10	960	<1.6	4.1	<0.1	0.01	0.41	<2.1

Water quality instruments (purpose designed and widely commercially available) were regularly calibrated against purchased standard solutions prior to use.

4.10 Record Storage

The remediation works were recorded in the form of daily diaries and supervisors reports from supervising personnel (IKM – see Appendix R and S for details) and regular progress reporting by the main contractor (I&H Brown). Regular progress meetings were also held on-site, with attendees from NGPH, Worley Parsons (NG's appointed supervisors) and I&H Brown.

All contract records, including survey, sampling and monitoring records are held on remote servers controlled by I&H Brown and subject to regular back-up. I&H Brown also currently hold all verification samples from excavation bases / side walls and ex-situ treatment batches, should any cross -check testing be required.

4.11 Summary

Verification records can be used to demonstrate that:

- All significantly contaminated material was excavated from within Area AC2 and transferred for ex-situ treatment;
- All treated material was replaced in the excavation area in a form and condition that does not constitute a significant risk to current site users or local controlled waters through leaching;



- Area AC2 no longer acts as a source zone for dissolved phase contamination in groundwater flowing off-site to the north and west, or a source of free phase hydrocarbon contamination in Bedwell Brook;
- Area AC1 has been subject to significant reductions in dissolved phase contaminant loading and residual contaminated groundwater does not warrant further treatment or control;
- All significantly contaminated sediments have been excavated from the Bedwell Brook channel and Pond 2 and associated surface water drains have been cleared of contaminated sediment, debris and associated free phase hydrocarbons;
- There has been no significant negative impact on surface or groundwater quality around the site perimeters as a result of the works.

4.12 Testing Regime and Monitoring

4.12.1 Chemical Testing Regime

Remediation works were subject to both on-site and off-site chemical testing for a wide range of chemical parameters, allowing comparison against baseline conditions and specified remediation targets.

On-site testing was available for:

- Total (methanol/tetrahydrofuran extractable) petroleum hydrocarbons; total GRO and DRO petroleum hydrocarbons, total aliphatic and aromatic fractions; total PAH, total USEPA16 PAHs and total BaP. Soil and water samples were tested;
- Electrical conductivity, pH, dissolved oxygen, redox potential and temperature. Water samples only tested.



On-site testing was conducted using a QED analyser supplied by QROS Limited. All test results files from the analyses, including UV fluorescence spectra and internal instrument calibration and blank checks are presented in Appendix P. The QC controls applied to the QED analyses have been described in the preceding section.

All site water measurement data are presented on site monitoring data tables contained in Appendix R. Site measurement instruments were regularly calibrated against external standards provided by established commercial vendors.

Off-site testing was available for:

- NG suite of parameters; aliphatic / aromatic petroleum hydrocarbon profiles and asbestos. Soil and water samples tested;
- 10:1 Leachate extractions, with testing of leachate for the NG suite of parameters (BS EN 12457). Soils / treated materials only tested.

All off-site testing was conducted by DETS Limited. All DETS results certificates are contained in Appendix M.

Ex-situ treatment samples were tested separately under the control of the specialist contractor, HBR, who utilised a different commercial laboratory (i2 Analytical Limited) for both 10:1 leachate testing (BS EN 12457) and the long term tank tests. Analytical certificates from i2 are also contained in Appendix M.

Laboratory QA/QC issues are also discussed in Section 4.12.3 below.

4.12.2 Physical Testing and Measurement

The only physical insitu testing carried out during the works was plate bearing testing of natural materials in the base of Area AC2 excavations and of backfilled treated materials within the same area.



Plate bearing tests were conducted using equipment provided by the specialist contractor involved and testing locations and results have been described in earlier sections of this report (Section 4.8). Test certificates for the geotechnical testing are provided in Appendix N.

4.12.3 Laboratory Quality

As described in earlier sections of this report, off-site testing was carried out by accredited commercial laboratories with a long track record of providing analytical services to NGPH / I&H Brown (Derwentside Environmental Testing Services Limited (DETS) and the ex-situ treatment specialist contractor HBR (i2 Analytical Limited), respectively. The laboratories have fully documented methodologies for all the testing carried out, with the majority being MCERTS accredited (the exact method reference and accreditation status of each test result, is indicated on the individual analytical certificates provided – see Appendix M).

The laboratories both run extensive internal QA/QC procedures to maintain a high quality of analytical performance and to validate the results produced on a day to day basis. No QA/QC anomalies affecting Maelor Works site samples arose during the course of the remediation works.

4.12.4 Environmental Monitoring

Environmental monitoring during the remediation works was conducted in accordance with the agreed Site Health Safety and Environment Plan, that included noise, dust and vibration monitoring around the main excavation and ex-situ treatment areas, as well as VOC monitoring in the breathing zone around the site perimeter and within the main excavation areas.



Limited issues reported during the works were:

- Nuisance lime dust emissions from the mixing of excavated materials in the open;
- Ex-situ treatment area, nuisance odours from exposed tar contaminated materials and temporary stockpiles close to the southern excavation area perimeter;
- Occasional complaints due to vibration / noise during the breakout of extensive reinforced concrete foundations within the Area AC2 excavation area. These issues were managed on a reactive basis, without the need for significant additional mitigation measures, or changes to works methodologies.

Responses to these issues are recorded in daily site diaries (Appendix S) and SHSEP monitoring results were recorded throughout the works by the main contractor. The location of monitoring points are indicated on Figure 14. Results from the various monitoring measurements were recorded into the central site monitoring record (a MS Excel spreadsheet that was updated continuously throughout the works by the main contractor). A copy of the final spreadsheet, containing all the environmental monitoring records is presented in Appendix R.

4.13 Environmental Incidents

Two environmental incidents occurred during the works:

- The rupture of an unrecorded fire hydrant pipe (containing high pressure raw river water) by sheet piling along the eastern perimeter of Area AC2. This resulted in the rapid flooding of the excavation area and release of water into the site surface drainage (which discharged directly to Bedwell Brook). The rapid rise in water levels in the brook and the turbid appearance of the water resulted in the incident being promptly reported to Natural Resource Wales (NRW), who attended the site within an hour of the report.



No-one on-site initially had any record or knowledge of the hydrant pipework, but the local water utility company eventually traced the location of a cut-off valve in the adjacent Wrexham Industrial Estate (approx. 1km from the site). The hydrant was then isolated and a local repair was completed the next day.

NRW confirmed that no impact was visible beyond the confluence of Bedwell Brook and the River Clywedog (approximately 500m downstream of the site) and no impacts were reported by the River Dee Catchment Monitoring Network (which monitors the Clywedog). No further action was deemed appropriate by NRW.

- A low pressure, local gas supply pipe (yellow polythene) was ruptured by a track excavator during excavation within the designated Area AC2 excavation. The pipe was not marked on any available service plans, was not provided with any marker tape or boards and did not invoke a response from the cable detection tool that had been deployed in advance of the excavation. Again, no-one on site had a record or knowledge of its presence, but the local WWU staff quickly traced the adjacent isolation valve and turned-off the supply. WWU personnel then also carried out the repair. I&H Brown staff re-buried the pipe and installed marker tape across the top of the exposed section. The service was also recorded on an updated service plan for the site.

Full incident reports were prepared for both incidents by I&H Brown and submitted to NG / discussed at site progress meetings where various follow-up actions were agreed. Copies of the finalised incident reports are contained in Appendix G.



5. FINAL SITE CONDITION

A final site plan is provided as Figure 15. Final Site Plan (Drawing No: A1-14890-3008). The site has been reinstated to the same overall surface condition and layout as was the case prior to the commencement of remediation works. The site continues to be used for commercial / industrial open storage, bottled gas distribution, commercial office activities and mechanical workshop and garage facilities. Bordering land has continued to be occupied / used unchanged throughout the works.

5.1 Remediation Areas

5.1.1 Area AC1

Area AC1 remains as an area of unused / derelict open land, partially covered with residual concrete floor slabs and with the large concrete sub-surface structure of the former spent oxide bunker (backfilled with street excavation spoil and large concrete debris) undisturbed in the centre of the area. This bunker appears to contain perched shallow groundwater, partially isolated (by the in-situ buried structure) from the main shallow groundwater body in natural granular strata and made ground to the north and south. Monitoring well MW11-02 remains in place and accessible for sampling / monitoring within the bunker area (see Figure 15).

Shallow groundwater to the north of the bunker has been affected by remediation works to a small degree, while groundwater to the south of the bunker has been subject to significant abstraction / removal activities, with that water having now been replaced by groundwater flowing into the area from the east and south.

Groundwater within Area AC1 continues to show minor impacts from historical leaching of local spent oxide deposits (removed by previous remediation works) and inflow of contaminated groundwater / localised hydrocarbon from the south. No impacts attributable to these contaminants are detectable / apparent in the surface water receptors beyond the immediate site boundary and further remediation is not considered justified.



Groundwater abstraction boreholes and monitoring wells remain in place to the north and south of Area AC1 and are all accessible for sampling / monitoring of groundwater in these areas (see Figure 15). The current groundwater quality within this area of the site has been determined as part of the environmental monitoring programme described in previous sections of this report.

5.1.2 Area AC2

Area AC2 has been reinstated as an area of open storage accessed from the pre-existing perimeter road and a replacement central axis road. The area has been finished with a surface layer composed of secondary coarse aggregate derived from broken out concrete / bricks and recovered limestone aggregate / quarry scalpings material that was the former surface layer for much of the area.

The surface layer is a minimum of 200mm in thickness and is underlain by compacted backfill composed of the solidified / stabilised treatment product from the remediation works. The backfill layer varies in depth from approximately 3m in the north of the site to 1.5m in the south. Treated materials are separated from the surface aggregate layer by an orange, plastic warning mesh across the entire backfill area.

The treated material backfill is a homogeneous clay soil like material of very low permeability but retains the solidified / stabilised tar, hydrocarbons and other gasworks process residues, immobilised in a cementitious matrix. Surface infiltration and sub-surface groundwater flow through the backfill is minimal, with deeper parts of the backfill further provided with sub-horizontal secondary aggregate drainage layers to allow passage of groundwater through the backfill area without penetrating the treated materials. The ground around the backfill area has been left undisturbed with granular alluvium providing relatively permeable natural flow paths for shallow groundwater around the backfill area.



The whole site is underlain by very low permeability, natural clay stratum that effectively isolates shallow groundwater from bedrock aquifers that lie at depth beneath the locality. Surface run-off from the area is collected by the existing surface water drainage network (including a reinstated length through the centre of the backfill area) that discharges to Bedwell Brook.

Residual contamination beneath site buildings and within underground service corridors has been identified and recorded (see Figure 10), with monitoring wells (MW99-205 and BH26B) remaining in place to the east of the excavation area (within and down hydraulic gradient from identified residual contamination locations).

The ex-situ treatment area to the east of Area AC2 has been cleared of all traces of the remediation work activities and has been returned to an open area of tarmacadam hardstanding. This area is also served by the surface water drains that discharge to Bedwell Brook.

5.1.3 Area AC3

Area AC3 has been reinstated to its former state as an artificial balancing / attenuation pond for the surface water drainage system that serves the southern sector of the site (Flogas distribution / storage yard). The outlet (overflow) pipe for the pond has been cleared and now operates more effectively to maintain pond water levels some 10-15cm lower than was previously the case. Removal of sediment from the base of the pond has more than compensated for this lower surface level. The base of the pond is now exposed clay, although vegetation debris is likely to accumulate again with time due to the surrounding trees / scrub habitat. No changes have been made to the pond catchment area or the drain discharge inlet, but the surface water drainage network has been cleared of hydrocarbon contaminated sediment / debris and will no longer act as a source of contamination to the pond itself.



5.1.4 Area AC4

Area AC4 has been reinstated to its former state as an artificial channel for conducting the flow of Bedwell Brook between the two culvert sections at either side of the site. The channel profile is essentially unchanged, with a series of minor pools and riffles due to the slight changes in gradient on the channel base. Channel banks are formed from natural clay deposits, apart from a section immediately downstream from the surface water drainage outfalls that is concrete lined (also unchanged by the remediation works).

The channel base has been cleared of soft sediment deposits and no longer releases visible oil globules or sheens on disturbance (by physical entry/mechanical means or by high level water flows).

The newly formed access ramp, from the main site access road, at the eastern end of the channel section has been retained to allow future access by maintenance plant as required.

5.2 Extent of Remediation Site End Uses and Constraints

As previously described, the site has been returned to the same use scenario as was existing prior to remediation, largely open space storage and distribution, with ancillary office and workshop/garage activities in existing buildings. No new development or change of use is currently envisaged or specifically allowed for.

No new constraints have been introduced by the remediation works. Constraints due to the presence of underground and overhead services remain. An updated site service plan has been produced using information gained from excavations and investigations conducted as part of the works.

A fully documented part of the site (Area AC2) is underlain by backfilled treated material (that contains tar, hydrocarbons and other gasworks residues in a solidified and stabilised form). This material is not exposed at the surface and does not present any risks to site users. However, its presence does need to be taken into account in the event of a need to disturb the sub-surface (for new development, maintenance or replacement of sub-surface services etc).



In addition, small areas of identified contamination (untreated) remain under existing buildings and roadways around the periphery of the backfill area. These locations are also fully documented and require the same degree of caution in the event of future disturbance / development.

The site surface water drainage network has been cleared of contaminated debris as part of the works, but continues to discharge directly to local surface water bodies (Bedwell Brook and Pond 2), with no treatment or attenuation. This is a continuation of the pre-existing situation, resulting from the old age of the original system and common design practice in the past. The system therefore remains vulnerable to any future spill or other release of polluting materials on the site surface, as this can be quickly transported directly to local controlled waters.

5.3 Residual Risk Assessment and Conceptual Site Model

The CSM developed for the site as part of the remediation design has been reviewed, along with the associated potential pollutant linkage table in the light of the completed remediation works.

Updated pollutant linkages are shown in Table 20 Post-Remediation CSM Linkage Table below, representing the site in its current use / condition and confirming the absence of any remaining significant pollutant linkages.

It is noted that any new development or change of use at the site should be accompanied by a further reassessment of the CSM and the data contained in this report to ensure that no new linkages or risks are created by such changes.



Table 20: Post-Remediation CSM Linkage Table

Site Area	Source	Pathway	Receptor	Current Site Conditions (post remediation)		
				Consequence	Likelihood	Risk
AC2	Solidified and stabilised homogenised made ground and natural alluvium containing gasworks process residues and asbestos fibres, placed at depth beneath granular cover layer and warning separator mesh.	Direct contact and dust / vapour inhalation.	Site users (including utility maintenance workers) and trespassers.	Mild, treated material is not dusty and has very low volatile content.	Unlikely – capping / warning layer in place, location of backfill well documented and any excavations will be planned and workers appropriately protected.	Low. No special precautions required for site use (including maintenance or installation of underground utilities).
AC2	Solidified and stabilised homogenised made ground and natural alluvium containing gasworks process residues and asbestos fibres extending into the saturated zone.	Migration / leaching by infiltration and shallow groundwater, followed by groundwater migration and movement through site drainage.	Third party field drains / ditches (linked to River Clywedog. Bedwell Brook	Negligible, backfill material has nominal leachability and is provided with preferential flow paths to minimise infiltration into / flow through backfilled materials.	Likely – previous drainage system largely retained.	Low. No further action required (other than normal drain maintenance).
AC1 AC4	Contaminated shallow groundwater in made ground and granular alluvium.	Migration along local hydraulic gradients / entry into surface water drainage.	Third party field drains / ditches (linked to River Clywedog. Bedwell Brook.	Mild, almost all ongoing contamination sources removed. Residual contamination unlikely to cause concentrations in Bedwell Brook or field drains to exceed surface water quality criteria at site boundaries.	Likely – but limited volumes suspected.	Low. No deterioration of surface water receptors.



Site Area	Source	Pathway	Receptor	Current Site Conditions (post remediation)		
				Consequence	Likelihood	Risk
AC1 AC2	Residual free phase tar and oils and hydrocarbon contaminated made ground present at shallow depth (peripheral to backfill area).	Direct contact / inhalation of vapour.	Site users / trespassers.	Mild, very small volumes of ground affected, all below impermeable surface cover (roadways or buildings).	Unlikely – direct contact pathway not present, vapour pathway negligible.	Low. No further action required under normal site use.
AC2 AC3 AC4	Sediments collecting in surface water drainage pipework and deposited in water bodies.	Flushing by infiltration and shallow groundwater, followed by discharge to surface water bodies.	Area AC3 pond / Bedwell Brook.	Negligible under normal conditions (potential for more severe impacts if fuel or other hazardous materials spilled on operational areas).	Unlikely - limited amounts of hazardous materials present on-site. All managed under controlled conditions.	Low. Management of hazardous materials needs continued vigilance.
AC1 AC2	Shallow groundwater within granular alluvium impacted by dissolved gasworks process contaminants.	Lateral migration along hydraulic gradient towards surface water.	River Clywedog.	Mild - no detectable rise in water concentrations under typical conditions.	Unlikely – due to limited volumes, absence of direct pathway.	Low. No remedial actions required under current conditions / use.
B EAST B WEST	Contaminated imported made ground (ash / clinker / coal mining spoil) in embankments and shallow surface layer. Not addressed by current remediation.	Direct contact and dust / vapour inhalation.	Site users / trespassers.	Moderate - exceedance of typical CLEA criteria, but bioavailability likely to be very low (due to nature of contaminated materials).	Unlikely – due to low usage of site / presence of soil / vegetation cover.	Low. No remediation action required under current site use.



Site Area	Source	Pathway	Receptor	Current Site Conditions (post remediation)		
				Consequence	Likelihood	Risk
B EAST B WEST	Contaminated imported made ground (ash / clinker / coal mining spoil) in embankments and shallow surface layer. Not addressed by current remediation.	Migration / leaching by infiltration and shallow groundwater, followed by groundwater migration and movement through site drainage.	Field drains / ditches (linked via third party drainage to River Clywedog. Bedwell Brook	Negligible – due to limited volumes. No detectable rise in water concentrations under typical conditions.	Likely – no controls in place.	Low. No remediation action required under current site use.



5.4 Residual Liabilities, Monitoring and Maintenance

5.4.1 Residual Liabilities

Minor residual and retained contamination constraints have been described in earlier sections of this report (Sections 3.8 and 4.7) and only have potential impacts in the event of a change of use or new development at the site (including new underground service installation or the maintenance / repair of existing services).

The site continues to actively discharge surface water drainage to Bedwell Brook (including via an overflow channel from Pond 2). Responsibility for the prevention of any polluting discharges (from spills or leaks in operational areas for instance) rests with the site occupiers / users.

Bedwell Brook also flows through two culverts within the site area and responsibility for the maintenance of these structures (including the trash screens at each entrance) lies with the site owner. This responsibility extends to the maintenance of the surface water drainage outfalls that discharge to the brook, any blockage of the outfalls could lead to back-up and surface flooding within the site.

Drainage of the northern and north western sector of the site area is not fully characterised and relies on external drains in agricultural land beyond the site boundary. Responsibility for these drains is assumed to rest with the land owner.

5.4.2 Monitoring and Maintenance

The Maelor Site does not require any further remediation effort under current site use scenarios. The remediated areas / materials do not require any ongoing maintenance or monitoring effort at this time.

No new or additional monitoring or maintenance requirements have been introduced as a result of the remediation works.



The site continues to be responsible for the quality of surface water discharges to surrounding controlled waters, although significant impacts due to historical site contamination have now been addressed and normal drainage discharges are no longer likely to cause pollution in the receiving waters. Current and likely future site uses continue to have the potential to cause pollution of local controlled waters and appropriate environmental management procedures are therefore required to address these risks. Periodic, routine inspection and sampling of controlled water receptors around the site is therefore recommended.

Normal debris clearance and sediment removal maintenance procedures will continue to be required for the surface water drainage network and the receiving Bedwell Brook channel / Pond 2. Culvert entrance trash screens should also be regularly cleared of debris.

If significant redevelopment or disturbance is planned within any of the remediation areas (including immediately adjacent parts of the site), it is recommended that the retained monitoring wells are utilised to provide up to date information on local groundwater levels and quality.



6. THIRD PARTY CONTACTS CONSULTATIONS AND WARRANTIES

6.1 Third Party Contacts and Consents

The remediation works have been conducted under the terms and conditions of a planning permission (application ref: P\2014\0658), demolition warrant (Ref: DM/1415/0012) and Ordinary Water Course Consent (Ref: WCBC OWC00002419), all issued by WCBC. Copies of the various consents are presented in Appendix C.

The principal contacts are:

Planning Officer – Matthew Phillips, Planning Officer/Swyddog Cynllunio, Wrexham County Borough Council/Cyngor Bwrdeistref Sirol Wrecsam. Telephone/Ffôn: 01978 298780. Email: Matthew.Phillips@wrexham.gov.uk

OWC Officer – Carole Wright, Technical Flood Support Officer, Wrexham County Borough Council/Cyngor Bwrdeistref Sirol Wrecsam, 16 Lord Street, Wrexham, LL11 1LG. Telephone/Ffôn: 01978 298829. Email: Carole.Wright@wrexham.gov.uk

The council also consulted with its own Contaminated Land Officers and relevant officers within Natural Resources Wales (NRW) as part of the planning application process. Planning consent was conditional on agreement from these same WCBC and NRW officers regarding the implementation of the Remediation Design. Principal contacts were:

Stacey Inglis, Contaminated Land Officer - Environmental Protection / Swyddog Tir wedi ei Halogi - Diogelu'r Amgylchedd, Housing & Public Protection Department, Ruthin Road, Wrexham. LL13 7TU. Telephone/Ffôn: 01978 297435. Email: Stacey.Inglis@wrexham.gov.uk

Elaine Wort, Swyddog Technegol, Geowyddor/Technical Officer, Geoscience, Cyfoeth Naturiol Cymru/Natural Resources Wales. Telephone/Ffôn: 0300 065 3828. Email: elaine.wort@cyfoethnaturiolcymru.gov.uk



The exclusion and management of protected species (principally great crested newts) during the works was conducted under the terms of European Protected Species Licence issued by NRW. The licence application included a detailed Method Statement covering the protection, exclusion and relocation elements required and a follow-up report that was submitted directly to NRW. A copy of the licence is provided in Appendix C and a copy of the Long-term Monitoring and Site Security Plan: Great Crested Newts Sign off Report is included in as Appendix T.

Copies of this Verification Report are to be provided to the local planning authority and to NRW as required by the planning consent conditions.

Waste treatment processes (water and soils) were conducted under the control of two separate permits held by the specialist contractors involved:

- HBR Limited;
- Geo² Limited.

Copies of the deployment forms for these treatment processes are contained in Appendix C and L respectively. No visits or further communications were received from the regulator during the course of the works. The regulator was informed of completion of the works and removal of treatment plant from the Maelor site, as required by the permit conditions.

6.2 Consultations and Site Visits

During the course of the works, regular liaison meetings were held with the designated contacts for the two site tenant organisations (WWU and Flogas). Minor housekeeping issues could also be dealt with by direct contact with the IHB site manager (no need to wait for the next scheduled meeting). Good relations were maintained throughout the works and full co-operation was received from WWU and Flogas personnel at all times. Records of the regular meetings were kept and copies of the minutes are provided in Appendix S.

As a result of pre-works discussions, contaminated land officers from WCBC accepted an invitation to an informal site visit, which included a guided tour of the site excavations and ex-situ treatment area and an update on the progress of the works. There were no matters arising or formal correspondence associated with this visit. The visit was recorded in the IKM Daily Diary, copies of which can be found in Appendix S.



6.3 Essential Wayleaves

No wayleaves or other access requirements remain in relation to the completed remediation works.

6.4 Warranties/Contract Maintenance

6.4.1 Warranties

Defects correction – in accordance with period stated in the Contract.

Collateral Warranty shall be provided if requested.

6.4.2 Contractual Maintenance

No maintenance is required by I H Brown Ltd. However, NGPH should be aware that NGPH have ongoing obligations as owner of the site, which they will need to determine and execute. For example the actions set out in the Long Term Monitoring and Site Security Plan as issued to NRW.



7. REFERENCES

Author / Date	Title	Doc Ref
IKM Consulting Limited July 2014	Areas A and C Stage 1 Risk Mitigation Site Investigations Factual Report V3	13627-REP-002 (IKM 2014 REP002)
IKM Consulting Limited July 2014	Area B East Stage 1 Risk Mitigation Site Investigations Factual Report V3	13627-REP-003 (IKM 2014 REP003)
IKM Consulting Limited July 2014	Area B West Stage 1 Risk Mitigation Site Investigations Factual Report V3	13627-REP-004 (IKM 2014 REP004)
IKM Consulting Limited September 2014	Risk Assessment and Remediation Design Report V4	13627-REP-005 (IKM 2014 REP005)
IKM Consulting Limited November 2014	Garage Investigation Report	13627-REP-006 (IKM 2014 REP006)
IKM Consulting Limited December 2014	Garage Investigation Report (Factual)	13627-REP-007 (IKM 2014 REP007)
IKM consulting Limited April 2015	Method Statement and Species Protection Plan: Great Crested Newts	13627-REP-008 (IKM 2015 REP008)
IKM Consulting Limited September 2015	Long Term Monitoring and Site Security Plan: Great Crested Newts	14890-REP-002 (IKM 2015 REP002)
Komex Clarke Bond February 1996	Final Environmental Assessment - Factual Report of Maelor Works, Wrexham Clwyd	Report 50065
Komex Clarke Bond December 1998	Post Remediation Report for Radiological Survey and Remedial Works at Maelor Works, Marchwiel, Wrexham and EM Edwards Works, Llandarcy Neath.	Report 50117, 50117-1 & 50118 (one document)
Komex Clarke Bond November 1999	Factual Additional Site Investigation at Maelor Works, Wrexham	Report 50065-6



Author / Date	Title	Doc Ref
Komex Europe December 2000	Hydrological and Hydrogeological Investigation at Maelor Works, Wrexham	Report 50065-6
Komex Europe February 2001	Factual Post Remediation Report for the Former Gasworks Maelor Wrexham.	Report 50065-17
National Grid Property Holdings 2013	Core Specification	
Worley Parsons Komex August 2006	Factual Site Report - Area A - Former Gas Works - Maelor Works - Wrexham	Report 50065-25
Worley Parsons January 2012	Environmental Assessment Site Investigation Report - Maelor Works, Wrexham. RevB.	Report 50065-29



8. GLOSSARY

Word/Abbreviation	Meaning
ACM	Asbestos Containing Materials.
Alluvial/Alluvium	Sediments deposited by flowing water. Typically granular (sand and gravel) or cohesive (silt and clay).
Ancillary works	Supporting work undertaken before main activities commence.
Area AC	NGPH designated site areas: Area A and Area C, which together form the majority of the main former gasworks complex within the current Maelor Works.
Area B (East) and (West)	NGPH designated site area, Area B. Split into two parts, one to the east of Area AC and the other to the west. Occupying the former rail corridor through the site.
Aromatics	Organic compounds containing one or more benzene type carbon ring structures. Major constituents of coal tar and other hydrocarbon products (including industrial solvents).
bgl / mbgl	Below ground level / metres below ground level.
Borrow pit	A pit created when earth or rock is excavated for use in local construction.
Carboniferous Coal Measures	Layers of sedimentary rock that can contain coal seams, originating from the Carboniferous geological time period.
CLEA	Contaminated Land Exposure Assessment spreadsheet based model, originally sponsored by the England and Wales Environment Agency.
Confluence	Where two surface water courses meet and join together.
Contamination indicators	Any differentiating signs that suggest a material or location may be impacted by contamination (visible, odorous or instrumentally measurable)
CSM	Conceptual Site Model.
CWG plant	Carburetted Water Gas plant.
DETS	Derwentside Environmental Testing Services Limited, a commercial chemical testing laboratory.
Dissolved phase	Contamination dissolved within an aqueous phase (surface or groundwater).
DNAPL	Dense (denser than water) non-aqueous phase liquids (will tend to sink to the base of any surface or groundwater bodies).
Drainage outfalls	The discharge point of a drainage system.
ECOW	Ecological clerk of works.
Flogas	Flogas Limited, a supplier of bottled and cylinder gas products and a tenant for large parts of the Maelor site.
Free phase	A liquid contaminant present as an identifiable layer or continuous mass, separate from surface water or groundwater bodies.
French Drain	A ditch or trench filled with aggregate, gravel or similar, which intercepts and redirects surface and sub-surface water flows.



Word/Abbreviation	Meaning
Glacial Drift	Sediments deposited by ice sheets and water formed by melting ice. Can be both clay rich or mostly sand and gravel, or indeed mixed and heterogeneous.
GGBS	Ground granulated blast furnace slag.
IHB	I&H Brown Limited, the main contractor for the remediation works.
IKM	IKM Consulting Limited.
LNAPL	Light (less dense than water) non-aqueous phase liquids (will tend to float on top of any groundwater or surface water bodies).
Made ground	Sub-surface layers or irregular deposits composed of artificially placed materials (which can be of almost any composition).
NEWDO	North East Wales District Office.
NGPH	National Grid Property Holdings Limited.
NRW	Natural Resources Wales, the main environmental regulator for Wales.
OWC	Ordinary Watercourse Consent, required for most works within a surface water course.
PAHs	Polycyclic aromatic hydrocarbons, toxic organic contaminants often associated with coal tars and combustion residues.
Perched groundwater	Sub-surface water held at an artificially high level by low permeability materials below it.
Phenols	A range of toxic organic compounds containing one or more phenol groups, commonly associated with coal gas processing residues.
Pollutant Linkage	A connection (pathway) between a contamination source and an identified receptor. All three elements must be present for a linkage to be confirmed.
Aquifer (Principal)	Sub-surface layers or bodies of sediments containing utilisable or otherwise significant volumes (bodies) of free water (Principal aquifers are those that represent the most important or significant local groundwater bodies).
QA/QC	Quality Assurance and Quality Control.
QED analyser	UV fluorescence spectrometry based analytical instrument supplied by QROS Limited.
Re-bar	A concrete reinforcing bar made of steel.
ROF	Royal Ordnance Factory, historically responsible for the production of munitions (at multiple sites across the UK)
Scalpings	Low grade, crudely processed overburden or weathered strata from a quarry.
Screening / riddling	Separation of oversize fragments from a soil or other granular matrix using shaking grids (screening) or perforated excavation buckets (riddling)
SHSEP	Site Health Safety and Environment Plan
Strip footings	A concrete strip that lies across a soil base to distribute the weight of load-bearing walls.



Word/Abbreviation	Meaning
TPH	Total petroleum hydrocarbons (usually refined products such as fuels and lubricating oils).
Trial pitting	Pits dug prior to construction to sample the structure and composition of the ground and identifying things such as geology and water table of the site.
Triassic Sherwood Sandstone	Typically red sandstone or clay rich rocks laid down in desert conditions, during the Triassic geological time period.
Visual / olfactory signs	Contaminant indicators that are apparent from visual inspection and odour emissions.
VOC	Volatile organic compounds, a generic term for organic compounds that are volatile (readily enter the vapour phase) at typical ambient temperatures.
Watershed	The line (of highest elevation) that separates two or more drainage systems (surface water or groundwater), with water flowing in different directions on each side of the line.
WCBC	Wrexham County Borough Council.
WP	WorlyParsons Europe Limited.
WTF	Water Treatment Facility.
WWTW	Waste Water Treatment Works.
WWU	Wales and West Utilities Limited, a local energy supply company that is a tenant and land owner at the Maelor site.



FIGURES

Figure 1

Site Location (Drawing No: A1-13627-3051)

Figure 2
Pre-Remediation CSM Plan
(Drawing No: A1-13627-3050)

Figure 3
Location of Remediation Areas
(Drawing No: A1-14890-3005)

Figure 4

Area AC1 Remediation Plan (Drawing No: A1-14890-3003)

Figure 5

Area AC2 Remediation Plan (Drawing No: A1-14890-3004)

Figure 6

Service Location Plan Area AC (Drawing No: A1-13627-3048)

Figure 7

Drain Clearance Locations (Drawing No: A1-14890-3011)

Figure 8

Area AC3 Remediation Plan (Drawing No: A1-14890-3006)

Figure 9

Area AC4 Remediation Plan (Drawing No: A1-14890-3007)

Figure 10

Residual Contamination Plan (Drawing No: A1-14890-3010)

Figure 11

Groundwater Contour Plot during Abstraction (Drawing No: A1-14890-3009)

Figure 12
Area AC1 Groundwater Levels Charts

Figure 13
AC2 Excavation Grid Squares and Sample Locations
(Drawing No: A1-14890-3002)

Figure 14
Peripheral Receptor Monitoring Locations
(Drawing No: A1-14890-3001)

Figure 15

Final Site Plan (Drawing No: A1-14890-3008)

APPENDICES

Appendix A

Handback Documentation and Pre-Start Survey Records

Appendix B
As Built Programme

Appendix C
Consents and Licences

Appendix D
Aurora Radiation Screening Report

Appendix E
Site Photographs

Appendix F
HBR Limited Treatment Records

Appendix G
Incident Reports

Appendix H
Demolition and Waste Management Records

Appendix J
Water Main Replacement Records

Appendix K
IHB Materials Management Plan

Appendix L
Geo² Reports

Appendix M
Laboratory Certificates

Appendix N
Geotechnical Testing Results

Appendix P
On-Site Testing Data

Appendix R
Site Measurement and Monitoring Records

Appendix S

Site Diaries, Advice Notes and Meeting Minutes

Appendix T
Ecological Reporting