English Partnerships
The National Regeneration Agency

Date: August 2003

WEIR PUMPS SITE, OLDHAM ROAD, MANCHESTER

Environmental Interpretative Report

Client: English Partnerships

Report Reference: 1001328/R/01B

REPORT CONTROL SHEET

English Partnerships
The National Regeneration Agency

PROJECT NAME: Weir Pumps Site, Oldham Road, Manchester

REPORT TITLE: Environmental Interpretative Report

REPORT REFERENCE: 1001328/R/01B

Version	Prepared by & date	Checked by &date	Approved by & date
A. Preliminary Draft	Neil Balderstone January 2003	Sarah Claxton January 2003	John Crowther January 2003
B. Draft for Client Comment including Area 4 and Groundwater Risk Assessment	Neil Balderstone August 2003	Sarah Claxton August 2003	John Crowther August 2003

This report has been prepared by *Parkman Environment* on the basis of the available information received during the study period. Although every reasonable effort has been made to obtain all relevant information, all potential contamination, environmental constraints or liabilities associated with the site may not necessarily have been revealed.

Parkman has also used reasonable skill, care and diligence in the design of the investigation of the site. The inherent infinite variation of ground condition allows only definition of the actual conditions at the location and depths of exploratory holes, while at intermediate locations conditions can only be inferred.

To a degree the completeness of the investigation was restricted by the need to accommodate the requirements of English Partnerships and Weir Pumps Ltd, the site owners and occupiers.

This report has been prepared and written for the exclusive benefit of English Partnerships for the purpose of providing environmental information relevant to the potential statutory liability of the site and data relevant to the redevelopment of the site. The report contents should be only used in that context. Furthermore, new information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

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EXECUTIVE SUMMARY

Introduction	Parkman were appointed by English Partnerships (EP) by email dated 9th October 2002 to design and supervise a geo-environmental ground investigation. The works were carried out under SWR No NGE02001.
Site Location and description	The site is located in East Manchester, at NGR SJ 872 998. The site covers an area of approximately 16ha and has been subdivided into 4 distinct areas. Area 1:- vacant area of land formerly occupied by a large machine shed. Area 2:- land occupied by the cricket pitch and former backfilled reservoir. Area 3:- vacant area of land bounded by Grimshaw Lane and the Manchester to Ashton Railway. Area 4:- vacant land to the north of the Foundry building, bounded to the north by Bower Street and to the south by the Rochdale Canal. The site was developed between 1893 and 1900, with the construction of an Engineering Works. Numerous clay pits are recorded on the site, which were backfilled by 1922. In addition, the reservoir in the south west of Area 2 was backfilled in 2002. Site generally comprises granular and clayey made ground overlying thick (up to approximately 30m) Glacial Till, overlying Sherwood Sandstone and Coal Measures. It is anticipated that ground movements associated with coal workings have now ceased. The nearest watercourse is the Rochdale Canal on the northern boundary of the site. The River Medlock is some 400m to the south. The Sandstone is a major aquifer while the Coal Measures are a minor aquifer. Axis Ltd were contracted to carry out an ecological survey of Areas 1-3 and reported that the grassed parts of Area 1 and Area 3 are of potential floristic interest. The presence of numerous mature trees and cellars on site offer potential roost sites / hibernacula for Bats. A small area of Japanese Knotweed was recorded in the north east corner of the site, which will require treatment prior to development. In addition another small stand was noted by Parkman staff during the site works in the vicinity of TP21 and around Area 4.
Previous Ground Investigations and Desk Studies	The following previous reports have been reviewed: Environmental Audit Report, MEL Ltd 1995, PB Kennedy and Donkin, 1999 and Ove Arups 2002. Each report summarised the site and generally indicated the presence of sources of contamination. In Area 1, the former fire test area and former power house; Area 2, the former reservoir and clay pit and former bituminous coatings plant; Area 3, no significant sources were identified. Area 4 was not studied in detail by previous desk studies.
Site Investigation	The first phase of the investigation comprised eleven cable tool boreholes and forty machine excavated trial pits across Areas 1-3. Trial pits were required to prove at least 1m thickness of Glacial Till and boreholes, to prove at least 5m thickness of Till. Following the findings of phase 1, phase 2 was carried out and comprised ten deep trial pits to 6.00m to prove depth of made ground across Area 2 and nine machine excavated trial pits to prove at least 1m thickness of Glacial Till in Area 4. In addition, two cable percussive boreholes in Area 2 and two in Area 4 were programmed. One borehole in each area was to target deep groundwater and to prove thickness of Glacial Till. Both phases of site works were designed and monitored full time by Parkman, who also scheduled the chemical and geotechnical testing.
Physical Ground Conditions	Ashy and clayey made ground was present across each area of the site. Made Ground across Area 1 was generally about 1m thick, up to 3m in

	places. This was overlying generally firm to stiff glacial clay. Ground water tended to be perched within the made ground. Soil gas was present up to Characteristic Situation 2 of CIRIA Report 149. Area 2: Made ground varied from 1m thick to 6.00m thick within the former backfilled reservoir, overlying firm to stiff glacial clay. Groundwater tended to be within the made ground, except in BH5 where deeper groundwater was encountered at 9.50m within the glacial till. Monitoring visits recorded deeper groundwater at approximately 22.00m bgl, within sand below the glacial clay. Soil gas was present generally as Characteristic Situation 2, although Situation 4 conditions were recorded in BH7. Area 3 made ground varied from 0.25m to 1.80m thick. No groundwater was encountered during excavation, but was however during monitoring. Soil gas was present as Characteristic Situation 1. Area 4 Made Ground varied from 1.00m to at least 4.00m thick, overlying glacial clay. Groundwater was generally encountered within the made ground, except in BH12 when deep groundwater was encountered at 6.20m depth within the glacial clay. Deeper groundwater was encountered during the monitoring visits at between approximately 17.00 and 24.00m, also within the glacial clay. Soil gas was present up to Characteristic Situation 2 of CIRIA Report 149.
Chemical Ground Conditions	Contamination samples were tested for a standard suite, including water soluble sulphate to BRE SD1, speciated PAH, DRO, PRO, LOI, and asbestos. Selected samples were tested for FOC, ferrous iron, manganese and PCB. Leachate and water samples were also tested for the same basic suite (except asbestos and FOC). Generic Guidelines used were generally CLEA for the soils and EQS and UKDW for the water and leachate. The initial screening of the results indicates that the 95% Upper Bound values for DRO were in excess of the human health threshold value, but generally less than the 2000mg/kg. Elevated concentrations of PCBs were located in the vicinity of the former power house in Area 1. The only other outlier detected was an elevated phenol concentration of 38mg/kg at 0.70m depth in Area 2. Asbestos was not detected in any of the samples for which it was tested. Analysis of made ground across the site identified elevated concentrations of copper and zinc and to a lesser extent boron, which may impact on plant life. Groundwater was generally contaminated with DRO, TPH and PAH and to a lesser extent chromium (VI), chromium, selenium and phenols. The DRO and copper contaminants present in the soil were generally also leachable.
Groundwater Quantitative Risk Assessment	A Quantitative Groundwater Risk Assessment (QRA) was carried out, based on published Environment Agency methodology. Areas 1-3 were combined for the purposes of the QRA. The results indicate that there is not a risk to the controlled waters within either Areas 1-3 or Area 4.
Recommendations	The proposed remediation strategy consists of the provision of hard standing, either across the whole site or as part of an industrial redevelopment with business units and landscaped areas. In addition, Japanese Knotweed will require treatment or disposal; any buried services will be required to be placed in clean trench fill and land drains and service ducts known to contain hydrocarbon contamination will require removal. A number of development abnormals exist including removal of the former service duct and remnant foundations, design and construction of piled foundations where deep made ground is encountered, gas protection measures in buildings, provision of clean trench fill, provision of landscaping areas, remediation of the Briscoe Lane boundary and if dewatering is

	required as part of redevelopment, treatment of shallow groundwater within Area 4, prior to discharge to the foul sewer. Further gas monitoring visits are recommended, but currently Areas 1, part of Area 2 and Area 4 of the site are classified by CIRIA 149 as characteristic situation 2. In addition, part of Area 2 is classified as characteristic situation 4, and Area 3 is classified as characteristic situation 1. Liaison with the Regulators is required to agree the scope of the remediation strategy and to arrange exemption from Waste Management Licensing Regulations and Landfill Tax.
Remedial Measures	Two basic options have been proposed for remediation of the site. The first involves provision of hard standing, ranging from provision of a medium term solution comprising a 250mm thick layer of inert granular hardcore to a permanent tarmac cover solution. The second option is for industrial redevelopment of the site with business units, hard standing and limited landscaped areas. Business units will require gas venting measures while landscaped areas will require import of a suitable material to act as an inert cover layer and planting medium. In addition, provision should be made for:- -Removal of any additional PCB contaminated material identified during re-development. -Additional testing possibly required to meet Environment Agency / Environmental Health Officer requirements. -Removal of land drains and reservoir drains. -Treatment of Japanese Knotweed. Costs for the removal of environmental issues associated with the site have been split into two options;- whole site cover and redevelopment. (Redevelopment does not include normal development costs such as foundations, hard standing, car parking or landscaped areas). Cover across the whole site – costs range from approximately £1.3M to £3.9M. Redevelopment - costs range from approximately £116K to £425K. Development abnormals include:- -removal of former service duct -piled foundations -gas protection measures -provision of clean trench fill -landscaping areas -remediation of the retaining wall at southern boundary of Areas 1 and 2. -if dewatering is required as part of redevelopment, treatment of shallow groundwater within Area 4, prior to discharge to the foul sewer. The range of costs do not include normal development costs for provision of hard standing or car parking. Costs range from £1.03M to £1.5M.

SECTION 1: INTRODUCTION

1.1 Terms of Reference

Parkman Environment were appointed by English Partnerships (EP) by email dated 9th October 2002 to design and supervise a geo-environmental ground investigation. The works were carried out under SWR Number NGE02001.

This ground investigation interpretative report reviews the physical and chemical ground conditions encountered during the two phases of site investigation and identifies potential constraints, including contamination, elevated soil gas and poor ground conditions. A groundwater risk assessment is included, together with recommendations for remedial action that may be required.

The area of the site is based on the boundaries as defined by EP for the study, and as indicated in Figure 2. Parkman Environment prepared this report based on the available information received during the study period.

1.2 Investigative Works

Two phases of works were carried out.

Phase 1 – November 2002 – Carried out by Ground Investigation and Piling (GIP). Chemical laboratory testing carried out by Geochem. Intrusive works comprised trial pits TP1-36 and boreholes BH1 to BH11.

Phase 2 – February and March 2003 – Carried out by Soil Mechanics. Chemical laboratory testing carried out by TES Bretby. Intrusive works restricted to Areas 2 and 4 and comprised trial pits TP2/1 to 2/10, TP37 to TP45 and boreholes BH12 to BH15.

1.3 Report Format

This report contains:

- A summary review of the previous desk study reports and environmental audit reports
- A description of the site, the site geology, hydrogeology and hydrology.
- Identification of the potential contamination sources within the study area, their potential receptors and possible pollutant linkages.
- The details of the ground investigations are reported
- The physical and chemical ground conditions encountered are reviewed
- Costed mitigation measures in view of the chemical ground conditions are presented
- An interpretation of the geotechnical ground conditions is outlined
- A final summary and conclusions are presented.

SECTION 2: SITE AREA

2.1 Site Location

The site is located in East Manchester, to the south of A62 Oldham Road, at National Grid Reference (NGR) SJ 872 998. A site location plan is presented in Figure 1. The site layout and site boundaries are presented in Figure 2.

The site boundaries comprise:

North Eastern Boundary: Ten Acres Lane

South Eastern Boundary: Briscoe Lane

South Western Boundary: The majority of the site is bounded on the south western side by Grimshaw Lane. However a small portion of land is located to the south west of the site, on the other side of Grimshaw Lane, and bounded by Grimshaw Lane and the Manchester to Ashton Railway.

North Western Boundary: The boundary follows the main entrance road to the fence in front of the Foundry. It then follows this fence line past the gate lodge to a point adjacent to the southern corner of the Oil Technology Centre, along the south eastern edge of the Oil Technology Centre, and around the northern boundary of the grassed area to the east of the Oil Technology Centre, up to Ten Acres Lane.

Phase 2 also included the area bounded by Bower Street, Ten Acres Lane, the Rochdale Canal and the Depot on Bower Street.

At the time of Phase 1 of the investigation, the Football Pitch, Bowling Green and Oil Technology Centre were part of the study area, but have been subsequently removed.

2.2 Site Description

The site covers an area of approximately 17 ha and for the purpose of this report has been subdivided into four areas based on historical usage. These separate areas are described below and the boundaries are defined in Section 2.1 and graphically in Figure 2.

2.2.1 Area 1 - Main Area:

Area 1 comprises the vacant area of land on the eastern side of the site. The Weir Pump offices, adjacent to the gate lodge, currently housing the Oil Technology Centre and the large green storage shed are not included in this area. These buildings are currently to be retained by Weir Pumps. A large shed containing the machine bays previously occupied this vacant part of the site. Demolition of the machine shed included removal of the concrete floor slabs. The area is generally level, however, adjacent to Ten Acres Lane, the land is raised approximately 1.50m. This raised level was also present within the machine shed, forming a walk-in basement, used for storage. Another raised area is present on the site of the former staff canteen and fire test areas, at the northern end of the Area.

Area 1 is approximately 1.5m higher than Briscoe Lane adjacent to the south eastern boundary. The difference increases to the south west, towards the boundary with Grimshaw Lane. A brick retaining wall approximately 4.0m high supports the level difference. Towards the Briscoe Lane / Grimshaw Lane junction, basements are still present below the concrete slab of the former Machine Bay 17, adjacent to Briscoe Lane. These basements were accessed via steps from Bay 17 and from gates opening onto Briscoe Lane at road level.

The ground level of Area 1 varied from 70.19 m AOD at TP18 to 74.7m AOD at TP1.

2.2.2 Area 2 - Sports Ground:

Area 2 comprises the land occupied by a grassed area, which formerly were the cricket pitch and a reservoir. There is an approximately 1.5m raise in level between the cricket pitch and the former reservoir. The boundary with Grimshaw Lane is a metre high soil slope adjacent to the former cricket pitch, becoming a brick retaining wall at approximately the position of the former reservoir. The difference in level between Grimshaw Lane and the site increases towards the junction between Grimshaw Lane and Briscoe Lane, up to a maximum of approximately 4.0m.

During Phase 1 of the ground investigation, Area 2 included the football pitch, but this has subsequently been removed from the study area.

The ground level of Area 2 varied from 67.8m AOD at BH7 to 70.8 m AOD at BH10.

2.2.3 Area 3 - Grimshaw Lane:

Area 3 is bounded to the north east by Grimshaw Lane, to the south west by the Manchester to Ashton Railway, to the north west by Lord North Street and to the south east by Briscoe Lane. The area is currently vacant and comprises a car park at the northern end at the same level as Grimshaw Lane. The southern end is grassland and scrub, formerly tennis courts. The site level is slightly higher than Grimshaw Lane and Briscoe Lane, the level difference increases towards Briscoe Lane, with the difference supported by a brick retaining wall.

The ground level of Area 3 varied from 63.32m AOD at TP34 to 68.79m AOD at BH9.

2.2.4 Area 4 – Bower Street:

Area 4 is currently vacant, bounded to the north west by Bower Street, to the north east by Ten Acres Lane, to the south east by the Rochdale Canal and to the south west by a depot and works. The most recent use of the area was as a car park and tarmacadam is still present. Trees, grass and shrubs occupy some former landscaped areas. The site slopes gently up towards Ten Acres Lane. A distinct change in slope of about 1m occurs half way along the length of the site.

The ground level of Area 4 varied from 70.54m AOD at TP37 to 74.07m AOD at TP38.

2.3 Site History

Prior to 1893, the site was essentially open fields. Between 1893 and 1900, Mather and Platt developed the site with the construction of an Engineering Works. By 1908, the site comprised the Park Engineering Works in the centre of the site. Numerous water bodies are marked, including a large 'pond' on the site of the cricket pitch. Railway lines cross Areas 2 and 3. Area 4 is largely undeveloped except for a few small buildings in the north eastern corner of this area. By 1922, the numerous 'ponds' have been infilled, with only the reservoir in the south west part of area 2 remaining. By 1931/32, the football and cricket pitches are marked and the foundry building and offices, together with the machine shed on Area 1 has been constructed. Area 4 was developed as a recreation ground by 1931. No further significant development has occurred until 1982/87 when the area appears much as it does today.

A more detailed site history is included in the summary of the reports in section 3 below.

The reservoir was backfilled recently on the advice of the Health and Safety Executive, using clay material excavated from the part of the site adjacent to Ten Acres Lane. It is understood from Weir Pumps that this excavated area was subsequently backfilled with imported material under the terms of an exemption from Waste Management Licensing granted to the site.

2.4 Site Geology

2.4.1 Drift

The British Geological Survey Sheet 85D 'Manchester Drift Edition', (scale 1" to 1 mile) indicates that boulder clay, now termed glacial till underlies the site. Previous investigations of the site show this is overlain over much of it by varying depths of made ground.

2.4.2 Solid Geology

The British Geological Survey Sheet 85S 'Manchester Solid Edition', (scale 1:50,000) indicates the north east half of the site is underlain by Bunter Sandstone, (now classified as Sherwood Sandstone) dipping south west at 25°. The south west half of the site is underlain by Westphalian C Coal Measures, together with a small area at approximately the location of the bowling green and social club, underlain by the Newton Heath Sandstone.

The boundary between the Sherwood Sandstone to the north east and the Westphalian C Coal Measures and Newton Heath Sandstone to the south is formed by the Bradford Fault, trending north west to south east across the site at a location approximately in line with the front of the Foundry and former machine shed. The down throw side of the fault is to the north east.

2.5 Mining

The site is partly underlain by Coal Measures and a Coal Mining Report was therefore requested from the Coal Authority. A copy is included in Appendix C.

The site is within the likely zone of influence on the surface from workings in three seams of coal at 140m to 600m depth. These were last worked in 1964. It is anticipated that ground movements from the above workings should have now ceased.

It is also noted that the site is within an area where coal is believed to exist at or near the surface and may have been worked at some time in the past.

2.6 Hydrogeology and Hydrology

The National Rivers Authority (NRA), (now The Environment Agency) Groundwater Vulnerability Plan of England and Wales, 1992, 1:1,000,000 scale, indicates that the site is underlain by a minor aquifer, with low permeability drift deposits. The Sherwood Sandstone underlying the north eastern part of the site is however classified as a major aquifer.

The nearest watercourse is the Rochdale Canal, which forms part of the northern boundary of the site.

The River Medlock lies approximately 250m to the south of the site and flows in a south westerly direction.

2.7 Ecology

A preliminary ecological survey of the site was requested by the client and provided by AXIS Ltd of Chester. A copy of their report is presented in Appendix D.

A preliminary survey was carried out to identify areas of potential interest only, so that fully detailed surveys could be undertaken at a more appropriate time of year if required as Axis raised concerns that December was not an ideal time of year to carry out an ecological survey of this sort.

The following species/groups were considered:

Vegetation, Great Crested Newts, breeding birds, bats, badgers and water voles

In addition identification of any stands of noxious weeds was requested. These included Japanese Knotweed, Giant Hogweed and Indian Balsam.

The grassed portion of Area 3 and the grassed area in the north corner of Area 1 were both reported to be of potential floristic interest. (Axis labelled these as areas A and B respectively). The poplar trees within Area 2 require identification, as they may be 'Manchester Poplar' a type of native black poplar.

The presence of numerous mature trees and two cellars on site are reported as offering potential roost sites/hibernacula for bats. It is recommended that these areas be examined for the presence of bats prior to development. Any trees scheduled for removal should be examined for evidence of usage by bats.

It was recommended that development of the potential bird breeding areas should be avoided during the breeding season of March to August.

A small area of Japanese Knotweed was reported in the northern corner of Area 1 (reported as Area B by Axis). The area of interest is only $2m^2$, but if not treated this has potential to spread quickly.

SECTION 3: PREVIOUS GROUND INVESTIGATIONS AND DESK STUDIES

Parkman has briefly reviewed the findings from previous environmental audit reports from MEL Ltd 1995, (including a Mather and Platt report dated 1962 and a Miller Environmental Ltd Report 1993), a PB Kennedy and Donkin report dated 1999 and an Arups Desk Study 2002. Copies of these reports are presented in Appendix D.

3.1 Mather and Platt, Record of the Ground Conditions and Numerous Excavation, February 1962.

This report notes the problems encountered when excavating foundations for shop columns, machine tools and pits. It is noted that some of the former clay pits were backfilled with virgin clay, while others were part filled with black slurry and capped with clay or backfilled with ashes, soil and refuse and capped to 1.20m (4ft) down with local clay.

Sand fissures were recorded and have been considered responsible for the failure of the foundry wall, allowing the facade to lean outwards by 19mm (7.5 inches).

The elevated ground forming the football pitch is recorded as being formed by tipping of the material excavated to construct the iron foundry. For several years after, the foundry refuse was tipped on both sides of the drive. This is believed to be in the area of the football and cricket pitches. It is noted that these areas were covered by 20mm (8 inches) of loam soil in 1948.

Running sand was recorded in the area of the works managers house, the power house, and the boiler house.

3.2 Miller Environmental Ltd, Contamination Investigation Report, 1993

Only section 5 (discussion of findings) and section 6 (recommendations) of this report were copied to Parkman. The site was split into two distinct areas during this ground investigation;

- The area adjacent to the canteen

Six trial pits were excavated here and three concrete air raid shelters were located. Hydrocarbon contamination was noted pooling at the base of the steps leading to the shelter adjacent to the canteen. The area was noted as being covered by red stone chippings overlying a fine grained dark infill material. Both materials were noted to be contaminated by fuels, oils and tars. Below these two strata the stiff brown clay was seen to be contaminated by fuels, oils and tars to a depth of 1.20m below the surface.

- The area adjacent to Ten Acres Lane

Four large air raid shelters were believed to be present in this area, but no immediate access was established. Trial pits were excavated in the area adjacent to the R&D

laboratories and adjacent to the fuel storage tanks and sprinkler test sheds. Underlying strata including the natural clay was noted to be contaminated with fuels, oils and tars to a depth of 1.20m.

Miller Environmental recommended that all contaminated ground above the suggested Dutch C criteria of 800ppm for TPH and 5000ppm for TEM (Toluene Extractable Matter), be excavated and removed from site.

No chemical test results or trial pit location plan was provided with the report.

3.3 MEL Ltd, Environmental Audit, Mather and Platt Works. 1995

MEL (formerly Miller Environmental Ltd) undertook an environmental audit of the Weir Pumps site on behalf of Weir Group (UK) Ltd. Mather and Platt Ltd, a subsidiary of Weir Group operated the site at this time. The MEL report is dated September 1995.

This report details the findings of a desk study and site walkover. Reference has also been made to a report by Miller Environmental dated January 1993 and an internal Mather and Platt report dated February 1962.

3.3.1 Site History

The MEL report briefly describes the former clay pits located on the site and the backfilling activities that took place to fill these pits. This information was taken from the Mather and Platt report and is described below in section 3.5.1.

3.3.2 Ground Conditions

Surface ground conditions are reported as differing thicknesses of stiff boulder clays with fine to medium sand lenses. These sand lenses were reported to have been fissured and in some instances flowing. They have been recorded as causing structural instability during foundation construction at various locations within the works.

3.3.3 Hydrogeology

Two known water abstraction wells are reported, both of which are south of the works. MEL note that the sand lenses may, if interconnected, provide pathways for contaminant migration.

3.3.4 Site Processes

MEL have divided the site into three main areas:

- Foundry: (Not part of the MEL audit)
- Machine shop and pump assembly area: (This building was demolished prior to Parkman carrying out their ground investigation).
- Wormald test area: (This area was demolished prior to Parkman carrying out their ground investigation).

The machine shop and pump assembly area is reported as generally having a concrete floor, which replaced the previous suspended wooden floor. MEL noted the machines utilise quantities of grease and other lubricating agents.

Miller Environmental previously investigated the Wormald (fire test) test area. MEL report that the findings from the Miller Environmental report dated 1993 noted considerable contamination in these areas from fuel oil and tar. Depth of the contamination was reported to be restricted by either local geology or by the presence of obstructions. It was noted that in areas underlain by boulder clay, contamination had penetrated up to 0.75m into the clay. Considerable amounts of free phase hydrocarbons were noted to be associated with land drains and pipework. The former containing quantities of heavy black tar.

3.3.5 Observations made during the site audit.

MEL reported six above ground storage tanks, only two of which remained at the time of the audit, located adjacent to the radiography facility, holding a total of 3100 litres (14,000 gallons) of diesel fuel oil. No bunding was noted and the upper layers of soil were reported as heavily stained with a brown oil type material. Three of these former tanks were present adjacent to Ten Acres Lane. At that time, an open excavation in this area showed oil contamination within the made ground.

The remaining surface tank was located in the central oil storage area, and was within a spillage bund. A portion of this area was noted as containing lubricants and showed frequent signs of spillage.

MEL noted they found indications of five underground storage tanks on the site. Two of these (one held petrol, the other benzene) were located below the central oil storage area. MEL noted neither tank had been decommissioned. An underground tank below bay 5B and a tank in the boiler house were noted on the 1968 historic map, but MEL could find no record of their presence, or whether they had been removed, during the walkover.

Chemicals were noted as being stored on site, adjacent to the point of use.

The reservoir at the front of the works was backfilled prior to Parkman commencing site works, but the reservoir was formerly used as a water storage facility. All surface drainage from the works drains into this reservoir, then into the sewer. MEL noted a brown layer of oil was floating on the surface and the clay bund around the reservoir was observed to be impregnated with oils.

MEL noted the presence of the 33kV transformer in the substation adjacent to Ten Acres Lane. They noted the possibility of PCB contamination in this area.

MEL note that the ‘black slurry’ reported as being used to backfill the clay pits may be coal tar, derived from the nearby gas works.

3.4 PB Kennedy and Donkin, Phase II Environmental Risk Assessment, Weir Pumps, Manchester. 1999

PB Kennedy and Donkin undertook a Phase II Environmental Risk Assessment for the Weir Pumps site on behalf of Manly Project Management Ltd. Their report is dated June 1999. The objective of this report was to identify significant environmental risks and liabilities associated with the site, prior to the purchase of the site.

3.4.1 Site History

County Series and National Grid Series historical maps dating from 1908 to 1993 are included in the PB Kennedy and Donkin Report.

1908 and 1909. The site is occupied by the Park Engineering Works, including railway sidings. A number of ponds are noted. The south east corner of the site is occupied by farm buildings. The area between Grimshaw Lane and the railway line is occupied by Wild's Farm and railway spur lines from the main line.

Page 11 which details the history from 1909 to 1951 is missing from our copy of the report

1951 to 1968. It is noted that a pump house and additional tanks have been constructed between the main buildings. Trees are noted around the sports ground. A bowling green, and running track are also noted.

1978/81 and 1982/87. The site is noted as being much as it was in 1968.

1990 to 1993. Little change is noted, apart from some demolition and reconstruction adjacent to Ten Acres Lane.

3.4.2 Site Works

Twenty six trial pits to a maximum depth of 3.20m were excavated. Logs are provided in the PB Kennedy and Donkin report. Forty two soil samples and one reservoir water sample were tested.

3.4.3 Ground Conditions

Page 14 is missing from our copy of the report.

- Reservoir Area: Made ground was identified to a maximum depth of 2.50m and comprised loose dark brown foundry sand with some ash and brick. Natural ground was not encountered.
- Recreation Area: Made ground was encountered to a depth of 3.0m, predominantly comprising ash, clinker and slag together with clay fill.
- Former Railway Sidings: Made ground was identified to a maximum depth of 1.8m, principally composed of ash, brick and soft clay fill.
- Where encountered, natural ground was noted as being generally firm to stiff brown silty clay (glacial till).

3.4.4 Groundwater

Minor seepages were noted in the made ground, particularly at the base, where it overlies natural clay.

3.4.5 Contamination Testing

Chemical testing was carried out on a number of soil, water and a few leachate samples. PB Kennedy and Donkin assessed the test results against ICRCL and Dutch guidelines.

Four main types of contamination were identified and are briefly discussed below:

- Heavy metals

These included arsenic, copper, nickel, lead, zinc, manganese and boron and were identified predominantly in the made ground, but were also identified in the natural clay.

- Phenol

Identified in three made ground samples including a sample of foundry sand.

- Polyaromatic Hydrocarbons

Identified within the made ground and believed to be derived from the bituminous coating process and the ashy made ground material.

- Petroleum Hydrocarbons

Believed to be derived from diesel, petrol and lubricating or cutting oil. Elevated samples corresponded to visual identification in the field.

In addition, elevated concentrations of copper, lead, mercury and manganese were reported as being present in leachate samples. The water samples recorded elevated concentrations of nickel, zinc and manganese when compared to Dutch Intervention Values, National Environmental Quality Standards or Drinking Water Standards.

3.4.6 Contamination Risk Appraisal

PB Kennedy and Donkin identified the following potentially significant sources of contamination, the reservoir and the area to the southeast of the reservoir (formerly occupied by the plating shop) and the fire test area.

They have also identified the made ground and drains as potentially minor sources of contamination.

3.4.7 Conclusions and Recommendations

Page 32 of the report is missing from the copy Parkman were provided with.

PB Kennedy and Donkin have reported that the potential for off site migration of contaminants appears to be relatively low while the concrete floor slabs are still insitu, but following removal of these, off site migration of contaminants should be expected to increase.

Further investigation is recommended within each of the identified sources of significant contamination. Remedial options proposed involve removal of the contamination hotspots from each of the identified sources of potentially significant contamination.

3.5 Ove Arup and Partners Ltd, Desk Study for Weir Pumps Site. 2002

Arup's undertook a Desk Study for the Weir Pumps site on behalf of Ask/Askler. Their report is dated September 2002. The report reviews the available data including previous ground investigations. The PB Kennedy and Donkin Risk Assessment report June 1999, summarised by Arup's has been discussed above.

3.5.1 Site Description

Arup's have divided the site into four area as follows:

- Area 1: The large area in the south east of the site, formerly occupied by the machine shed, but currently vacant.
- Area 2: The western part of the site currently occupied by the football pitch and social club, former cricket pitch and the backfilled reservoir.
- Area 3: The strip of land between Grimshaw Lane and The Manchester to Ashton Railway, currently vacant land, occupied by a former car park and scrubland.
- Area 4: The north eastern part of the site, comprising the area occupied by the remaining operational buildings of Weir Pumps, together with a car parking and storage areas. This area also includes the former car park to the north of the Rochdale Canal.

3.5.2 Site History

Arup's confirm the general geological and historical features noted in previous reports.

3.5.3 Environmental Issues

Arup's report one licensed abstractor of water 250m from the site for manufacturing and three further abstractions within 1km of the site for manufacturing and dust suppression.

There are nine discharge consents reported within 1km of the site, reported as generally being storm water sewer overflows into the River Medlock or its tributaries.

Four pollution incidents to controlled waters are reported within 1km of the site, two in the Rochdale Canal and two in the River Medlock.

3.5.4 Previous Ground Investigation

Arups have briefly summarised the findings of the Kennedy & Donkin report dated 1998 and the PB Kennedy and Donkin report dated 1999. (This later report has been summarised in section 3.2 above).

3.5.5 Site Assessment

Arups have summarised the conditions, contamination and development constraints associated with each area of the site. Their contamination assessment is based on the investigation carried out by PB Kennedy and Donkin in 1999.

Area 1:

Arups reported that there is potential for contamination from the former plating and bituminous coatings plant. They report that the 1999 investigation did not identify any contaminants other than those expected from the sites previous usage i.e. diesel type oils, phenols and metals.

Arups report that the glacial till is likely to be a suitable foundation stratum for shallow spread footings and that it may be possible to excavate made ground and to construct new development on conventional shallow spread footings. It is reported that the Glacial Till may provide a suitable formation for a lightly loaded ground bearing floor slab, although a more heavily loaded ground-bearing slab may require ground improvement.

Area 2:

Arups reported the two former reservoirs present a contamination risk, and contamination may be concentrated in any silt layers at the base of the ponds. Arups note that PB Kennedy and Donkin report significant concentrations of hydrocarbons in the base of the recently infilled reservoir. Arups have stated that there is potential for general contamination of the made ground across this area.

Arups have reported that the depth of made ground makes the use of shallow spread footings uneconomical and ground bearing floor slabs are also unlikely to be suitable. The made ground within the backfilled reservoirs is likely to be particularly variable and there is also a high risk of obstructions within the made ground.

Area 3:

Arup's report that no significant sources of contamination were identified within this area. Part of the area was formerly railway sidings and Arup's report that PB Kennedy and Donkin found 1-2m depth of made ground.

Arups recommend further investigation of the ground conditions and contamination. They go on to note that the current use, partly as a car park and formerly as railway sidings, suggest that future development as hard standing is feasible.

Area 4:

The only part of this area likely to be redeveloped is along the southern boundary of this area, currently occupied by offices and stores.

Arup's report that this area has a similar history to Area 1 and therefore contamination levels are likely to be similar. The area remains in use and users are isolated from the ground by the presence of buildings and extensive hard standing. Similarly, the buildings and hard standing reduce leaching potential.

Arups have not made any comments on development constraints since their scope of works did not cover redevelopment of this area of the site.

3.5.6 Recommendations

Arups have recommended that further work be undertaken to provide information for the development of a remediation strategy for the site, and to allow development options to be developed further. They recommend that a geotechnical and geo—environmental ground investigation is required. This should include further information on the nature of the glacial till and made ground, together with information on soil and water contamination, potential for soil gas, and leachate and groundwater testing, to determine to potential for off site migration of contamination.

SECTION 4: INITIAL CONCEPTUAL MODEL

4.1 Introduction to Statutory Liabilities

Section 57 of the *Environment Act 1995*, adds Part IIA (ss.78A-78YC) to the *Environmental Protection Act 1990* and contains the legislative framework for identifying and dealing with contaminated land. The regulations cover the following:

- Land to be designated as special sites
- Pollution of controlled waters
- Content of remedial notices, and persons to whom they should be copied
- Compensation for rights of entry etc.
- Grounds of appeal against a remediation notice

Local authorities (district councils and unitary authorities) are the enforcing authority for contaminated land and the Environment Agency for any land designated as a special site due to the nature of its contamination.

In identifying contaminated land, local authorities will be required to act in accordance with guidance from the Secretary of State. Section 78A(2) defines contaminated land as

(a) “land which appears…to be in such a condition, by reason of substances in, on or under the land that-

(b) significant harm is being caused or there is a significant possibility of such harm being caused; or

(c) pollution of controlled waters is being, or is likely to be, caused”

The Statutory Guidance defines what “harm” is to be regarded as “significant” to:

Human beings: death, disease, serious injury, genetic mutation, birth defects, or the impairment of reproductive functions. Disease is to be taken to mean an unhealthy condition of the body or some part thereof.

Living organisms or ecological systems: an irreversible or other substantial adverse change in the functioning of the habitat or site;

Property (buildings): structural failure or substantial damage, making them unfit for their intended purpose.

Other forms of ‘property’ considered under Part IIA include crops (including timber), domestically grown produce, livestock or other owned or domesticated animals and wild animals subject to shooting or fishing rights.

For there to be an environmental liability associated with the site there must be a source of risk, a receptor and a pathway between them, i.e. a pollutant linkage.

The previous ground investigation and desk study reports summarised above have identified a number of potential sources, pathways and receptors.

These are summarised below.

4.2 Sources

From the available literature, it is evident that a number of potential sources of contamination associated with the use of the site as an engineering works are present within the site boundaries.

The potential sources of contamination previously identified include:

- Widespread Made Ground around the site has been noted in each previous ground investigation as being ashy. A boiler house was present on site. Ash produced in the boiler may have been spread across the site for disposal. Ash is a potential source of heavy metals including arsenic, lead and mercury.
- Contaminated material may have been used to backfill the former reservoir and clay pits. Prior to backfilling of the reservoir in summer 2002, it was noted by MEL Ltd that the water and clay bund around the reservoir appeared to be contaminated with oils. Black slurry, ash and rubbish were noted by MEL Ltd as being used to backfill the former clay pits. The former reservoir that was present on site and noted to be contaminated by MEL has been backfilled recently. It is unknown if any of the service infrastructure feeding water to and from this reservoir, as well as the storm overflow pipe onto Grimshaw Lane was removed. Employees of Weir Pumps informed us that the reservoir was backfilled on the advice of the HSE by placement of clay material excavated from the part of the site adjacent to Ten Acres Lane. This excavated area was then backfilled with imported clay material.
- Grease and other lubricating fluids associated with the machinery in the now demolished machine shed situated on Area 1.
- Underground and over ground oil and fuel storage tanks have been noted on site. Contamination and frequent signs of spillage were noted around a number of these. MEL have reported the presence of a benzene tank below the central oil storage area, which was noted at the time of the MEL report as not having been decommissioned. There is therefore potential for a significant human health risk from the contents of this tank as benzene is a known carcinogen.
- A 33kV substation was present on site adjacent to Ten Acres Lane. A second substation was present to the northern end of Area 1. There is potential for Polychlorinated Biphenyl (PCB) contamination from these if the transformer fluid was allowed to drain into the ground, particularly during decommissioning.
- The fire test areas were noted by Miller Environmental Ltd to contain considerable fuel oil and tar contamination. Associated land drains and pipe work were reported as containing considerable amounts of free product

including heavy black tar. These drains and pipe work also act as pathways for migration of contamination.

- Dumping of excavated material during construction of the Foundry created the elevated area forming the football pitch. MEL reported that foundry refuse was tipped on both sides of the driveway, onto the area of the football and cricket pitches.
- Pooling hydrocarbon contamination was noted in the air raid shelters adjacent to the former canteen. In the same area, MEL noted that the ground, including the Glacial Till adjacent to the R&D laboratories appeared to be contaminated with fuels, oils and tars.
- Asbestos may have been present within the Machine Shed as fibrous lagging or as asbestos cement tiles.
- The Bituminous and Chrome Plating Plant, and the Cyanide Dipping Shed, approximately located within Bays 13 to 17 of the Machine Shed are potential sources of contamination including phenols. The concrete floors of the shed may have prevented contamination migrating into the underlying strata, but the original wooden floors may not have.

Area 1 has been significantly reworked since the MEL report was produced in 1995. The machine shed has been demolished and most of the concrete floor slabs have been removed. The shallow Made Ground across the whole of Area 1 has generally been reworked through placement of imported material to backfill any low lying ground areas. Weir Pumps appear to have given permission for tipping to be undertaken although waste management exemptions/licences do not appear to be available. The source and nature of this material is unknown and therefore this exercise may be bringing further contamination onto site. The data is not available to assess whether any tipped material would present an environmental risk and hence potentially incur further remedial costs. If material has been brought to site and the exercise does not comply with the Waste Licensing Regulations then Weir Pumps would probably be liable for the cost of its removal.

4.3 Potential Pathways

Pathways for contaminants to reach site users include direct contact, ingestion and inhalation. Direct contact refers to skin contact with the contaminated material. Ingestion refers to oral intake of contaminants. Inhalation refers to both the direct inhalation of dust as well as inhalation of vapours or soil gas.

These pathways are relevant for both users of the site well as site users associated with any works that involve excavation of the ground for purposes such as maintenance of services.

Leaching of contaminants from the soil offers a pathway to controlled waters. The relative thickness of low permeability Glacial Till overlying the bedrock will restrict the flow of groundwater and offer protection to the groundwater in the underlying bedrock. However, the presence of sand lenses was noted by MEL within the Glacial Till and may, if connected, represent an available pathway for migration of contaminants through the Glacial Till. Due to the structure of clay sediments and the presence of relatively thin, but laterally extensive sands and gravels within the Glacial Till the vertical hydraulic conductivity of the Glacial Till is typically an order of magnitude less than the horizontal hydraulic conductivity. Therefore it is anticipated that lateral migration of contaminants is more likely than vertical. Free phase liquid hydrocarbons can migrate through the ground or via groundwater. Due to the general low hydraulic conductivity of the materials presence it is likely that migration of free phase would be limited to relatively short distances of the order of a few metres to tens of metres depending on the nature of the source. Land drains are known to be present across the site are also known to contain free phase hydrocarbons. These present a rapid pathway for migration of shallow liquid contamination, however they are unlikely to transmit groundwater due to their depth.

The backfilled ponds and reservoirs have the potential to generate gas and vapours, which may in turn migrate presenting a risk to users of this site as well as adjacent areas.

4.4 Receptors

Principal receptors of contamination are site users, site infrastructure and controlled waters.

Site users, including maintenance workers are potential receptors of site derived contamination.

Infrastructure, particularly buried services, e.g. water mains, and building foundations, may be attacked by sulphates, acid conditions and hydrocarbons.

Both groundwater and surface water is considered to be controlled water. The site is underlain by both major (Triassic Sandstone) and minor (Coal Measures) aquifers, whilst the principal receptor for contaminants reaching the saturated zone in the Glacial Till at shallow depth is likely to be the River Medlock. Surface water and potentially groundwater are unlikely to flow into the Rochdale Canal, since its elevation is generally above that of the groundwater.

4.5 Summary of Pollutant Linkages

A number of pollutant linkages can be readily identified from the information provided with the reviewed reports.

The risk to current site users as a result of dermal contact, ingestion or inhalation of contaminated soils, waters, dusts or vapours is considered to be significant, particularly from the large number of sources of hydrocarbon contamination that have previously been identified, together with a significant coverage of made ground across the whole site.

The risk to site infrastructure is significant due to the identified sources of contaminants which could impact on buried services and foundations.

The risk to controlled waters is considered low due to the generally low hydraulic conductivity of the Glacial Till, its significant thickness and the significant distance to surface water receptors.

Land drains across the site are previously reported as containing free phase hydrocarbons. These land drains can provide an easy pathway for off site migration of shallow liquid contaminants, but not the groundwater.

SECTION 5: SITE INVESTIGATION

5.1 Rationale

Previous desk studies and ground investigations have identified potential sources of contamination associated with the site as well as identifying specific areas of contamination that may lead to statutory liabilities. A site investigation was designed to further identify the extent of the previously identified contamination and to investigate the extent of other potential sources identified through the desk studies. It was designed to assess the general made ground and natural ground conditions across the site and specifically targeted known potential contamination sources such as the backfilled reservoir and clay pits, the former substations, bituminous, chrome plating and cyanide dipping plants, the fire test area and the former tipping area now occupied by the football pitch.

This initial investigation was also designed to assess the groundwater quality and levels to assess the impact of site derived contamination on the groundwater. The Rochdale Canal was also sampled to assess the impact of any potentially site-derived contamination. Leachability of the soils was determined for analysis of the potential for contamination to leach into the groundwater.

The potential for gas generation particularly in the backfilled reservoirs and football pitch area was targeted by the investigation.

Soil parameters were also determined for analysis of the existing conditions and future design of building development.

Following a study of the findings of this first phase of ground investigation, English Partnerships requested that Parkman design additional works to further delineate the extent of the contamination found in Area 2 and also to investigate the ground conditions within Area 4. In both areas, deeper boreholes were proposed in order to identify the depth to bedrock and to enable monitoring of deeper groundwater.

5.2 Site Works

5.2.1 Phase 1

Phase 1 of the site investigation was designed and monitored full time by Parkman Environment who also scheduled the chemical and geotechnical analysis of soil and groundwater samples. Ground Investigation and Piling Limited of Wolverhampton (GIP) as term contractors for English Partnerships were contracted to carry out the ground investigation.

Initially nine cable percussive boreholes and thirty-four machine excavated trial pits were proposed. However, due to the ground conditions encountered, this was increased during the site works to eleven cable percussive boreholes and forty machine excavated trial pits. Site works were carried out between 18th and 29th November 2002. Each exploratory hole position was scanned with a Cable Avoidance Tool (CAT) by the contractor prior to excavation to check for buried services. In addition, hand excavated inspection pits were dug at each borehole position.

Exploratory holes were positioned to establish the extent of any potential contamination associated with known positions of former reservoirs and clay pits, industrial buildings and process areas, as well as to give general cover across the site with regard to both physical and chemical ground conditions.

Each trial pit was required to prove at least 1m depth of natural Glacial Till. Hand shear vane tests were carried out on each cohesive stratum. The results are included on the trial pits logs in Appendix A.

Boreholes were required to prove at least 5m depth of natural Glacial Till, except BH10 and BH11, where at least 2m depth of natural Glacial Till was required to be proven below the backfilled reservoir.

Monitoring standpipes were installed into each borehole to facilitate groundwater and gas monitoring. The contractor was required to monitor each installation for gas and groundwater prior to demobilising from site. Subsequent monitoring visits were programmed to be made on a weekly basis for four visits. The first being on 5th December 2002. The first return visit included taking groundwater samples from each borehole.

Samples of soil and groundwater were selected by Parkman for testing and sent to AlControl Geochem in Chester, GIP's selected laboratory for subsequent chemical analysis. Parkman selected samples of soil for geotechnical laboratory testing by GIP in Wolverhampton.

Four samples of the canal water were taken by GIP and Parkman scheduled these for testing at AlControl Geochem. These four water samples comprised a sample from upstream and downstream of the site and two samples from the section of canal alongside the site.

A copy of the factual report issued by GIP, which contains all the ground investigation data, including an exploratory hole location plan is presented in Appendix A.

5.2.2 Phase 2

At the request of English Partnerships, Parkman provided a brief overview of estimated remediation costs for each of the three Areas of the site, based on the known chemical and physical ground and groundwater conditions established through Phase 1 of the site investigation. Based on this estimate of remediation costs, English Partnerships requested that a second phase of site works were carried out to assess the conditions across Area 4 and the further delineate the extent of the known contamination within Area 2.

Phase 2 of the site investigation was designed and monitored full time by Parkman Environment who also scheduled the chemical and geotechnical analysis of soil and groundwater samples. Soil Mechanics as term contractors for English Partnerships were contracted to carry out this phase of the ground investigation.

Within Area 2, two cable percussive boreholes and ten (6.0m deep) machine excavated trial pits were proposed. Within Area 4, two cable percussive boreholes and six (4.5m deep) machine excavated trial pits were proposed. Site works were carried out between 27^{th} February and 12^{th} March 2003. In addition six trial pits (five from Area 2 and one from Area 4) were re-dug by Soil Mechanics on 27^{th} March 2003 in order to recover fresh water samples. Each exploratory hole position was scanned with a Cable Avoidance Tool (CAT) by the contractor prior to excavation to check for buried services. In addition, hand excavated inspection pits were dug at each borehole position.

Exploratory holes within Area 2 were positioned to further delineate the extent of known areas of contamination identified from Phase 1. Deep trial pits were proposed in order to ascertain the depth of the natural strata where Made Ground was deeper than 4.5m.

Exploratory holes within Area 4 were positioned to establish the extent of any potential contamination associated with known positions of former buildings as well as to give general cover across the site with regard to both physical and chemical ground conditions.

Each trial pit was required to prove at least 1m depth of natural Glacial Till. Hand shear vane tests were carried out on each cohesive stratum. The results are included on the trial pits logs in Appendix B.

One borehole in each Area was required to prove 10m depth of Glacial Till, including the presence or otherwise of sand lenses within the Glacial Till. In addition, one borehole within each Area was required to prove depth to rock-head.

Monitoring standpipes were installed into each borehole to facilitate groundwater and gas monitoring. The contractor were required to monitor each installation for gas and groundwater prior to demobilising from site. Subsequent monitoring visits were programmed to be made on a weekly basis for four visits, with the first return visit to include taking groundwater samples from each borehole. The first monitoring visit for Phase 2 being on 24^{th} April 2003.

Samples of soil and groundwater were selected by Parkman for testing and sent to TES Bretby in Burton in Trent, Staffordshire, Soil Mechanics selected laboratory for subsequent chemical analysis.

Three samples of the canal water were taken by Soil Mechanics and Parkman scheduled these for testing. A sample was recovered from close to the bridge with Ten Acres Lane, another from close to the bridge with Grimshaw Lane and the third sample from half way along the north western boundary.

A copy of the factual report issued by Soil Mechanics, which contains all the ground investigation data, including an exploratory hole location plan is presented in Appendix B.

SECTION 6: PHYSICAL GROUND CONDITIONS

6.1 General

The general sequence of ground conditions across this area comprised made ground over natural glacial till.

The made ground can be generally split into two types - granular and cohesive. The granular material was generally brown or dark brown clayey gravelly sand and clayey sandy gravel. The gravel and sand components were predominantly composed of ash, brick and clinker with timber, slag and plastic encountered in some exploratory holes. The cohesive made ground was generally reworked natural clay with a sandy gravel component of ash, clinker, brick and some slag.

Made ground SPT 'N' values typically ranged from 4 to 15

The glacial till generally comprised firm to stiff brown, mottled blue grey, slightly sandy slightly gravelly clay. SPT 'N' values typically ranged from 12 to 39. The gravel component was generally composed of mudstone, carbonaceous mudstone and sandstone with occasional coal. The base of the glacial till was proved in Area 2 at 18.50m and in Area 4 at 27.00m.

Below the glacial till, medium dense, light brown fine and medium sand was encountered. Within Area 2 this became gravelly below 26.50m depth.

Rock-head was proved at 29.00m depth where grey highly weathered mudstone was encountered.

The whole site was split into four distinct areas, described above and presented on Figure 2. The GIP and Soil Mechanics factual reports present exploratory hole location plans for Phase 1 and Phase 2 respectively. The physical ground conditions for each area are described below.

Geotechnical laboratory testing was carried out on a number of samples and the results are presented in the GIP factual report presented in Appendix A. It is understood that Area 1 is the most likely area to be redeveloped and has therefore been considered in the most detail.

6.2 Area 1

The investigation of Area 1 comprised 29 machine excavated trial pits, TP1-21, TP24, TP26, TP35 and TP36. and three cable percussive boreholes, BH1-3. Table 1 below identifies the borehole reference numbers and the proven depth of made ground and glacial till, together with brief details of the standpipe installations.

Borehole No.	Made Ground: m AOD	Glacial Till: m AOD	Standpipe response zone: m AOD	Response Zone Target
BH1	72.47 - 71.77	71.77 – 64.47	70.97 – 65.47	Glacial Till
BH2	71.11 - 69.71	69.71 - 62.61	70.11 - 69.71	Made Ground
BH3	70.40 - 70.30	70.30 - 60.40	68.40 – 64.40	Glacial Till

Table 1. Borehole and standpipe details

6.2.1 Made Ground

Made ground was encountered in each exploratory hole within Area 1 and generally comprised thin cover up to approximately 1.4m thick. However, made ground up to approximately 3m thick was encountered in the northern part of Area 1, where ground levels were approximately 1.5m higher than the rest of the area. TP20 in the southern corner of Area 1 encountered made ground to the base of the pit at 4.00m. The pit was terminated at 4.00m as the JCB was unable to excavate any deeper.

The made ground can be subdivided into two main layers;

Granular ashy fill, generally comprising loose brown occasionally clayey gravelly SAND with occasional cobbles and some boulders. Occasionally tended towards sandy GRAVEL. The gravel generally comprises brick, ash, clinker, slag and concrete. Cobbles generally comprise brick and concrete. Boulders generally comprise concrete. Metal, glass and timber fragments were also noted.

Cohesive reworked Glacial Till, generally comprised firm and stiff brown sandy gravelly CLAY with some cobbles. Gravel is generally brick, ash, carbonaceous mudstone quartz and coal. Cobbles are generally brick. Metal, timber, glass and plastic fragments were also encountered.

Generally the granular made ground is encountered above the cohesive, but occasionally they are inter layered.

6.2.2 Natural Glacial Till

Glacial till, where encountered, generally comprised firm, becoming stiff and very stiff with depth, brown, mottled blue grey sandy gravelly, in places friable, CLAY, with some sand pockets. Gravel is generally carbonaceous mudstone, coal, quartz, sandstone and mudstone.

6.2.3 Groundwater

Exploratory Hole	Elevation of Water Strike m AOD	Strata	Notes
BH1	71.67 and 70.47	Glacial till	Slight seepage
TP2	71.62	Glacial till	
TP3	70.29	Glacial till	
TP5	70.76 and 70.26	Possible made ground	
TP8A	70.52	Made ground	
TP12	68.23	Glacial till	Slight seepage
TP13	69.01	Glacial till	Hydrocarbon sheen on water
TP15	70.24	Made ground	Slight seepage
TP16	70.78	Made ground	Within buried service chamber
TP16A	69.66	Land drain	
TP16A	69.46	Made ground	Slight seepage
TP17	69.90	Made ground	
TP17	68.60	Land drain	Hydrocarbon sheen on water
TP24	69.65	Made ground	Slight seepage
TP36	70.85	Land drain	

Table 2. Groundwater strikes during site works

Monitoring of water levels in all of the borehole installations was carried out by GIP on four occasions. Soil Mechanics were instructed to monitor all boreholes on an additional four occasions. The results of this monitoring are shown in Table 3 below, with depths in m AOD.

Borehole	Response Zone Target	29th Nov 2002	5th Dec 2002	12th Dec 2002	18th Dec 2002	3rd April 2003	25th April 2003	7th May 2003	30th May 2003	4th June 2003
		Groundwater elevation (m AoD)								
BH1	Glacial Till	71.25	71.07	71.07	70.87	71.07	70.81	71.12	71.08	70.93
BH2	Made Ground	Dry	Dry	Dry	Dry	Borehole Lost				
BH3	Glacial Till	67.36	68.50	68.50	68.50	69.37	68.54	68.77	69.01	69.04

Table 3. Groundwater monitoring results – after completion of site works

A complete set of water samples were taken from the boreholes installations for chemical analysis by GIP. A second set was subsequently taken by Soil Mechanics. These results are discussed in Section 6.3.

6.2.4 Soil Gas

Soil gas levels have been monitored in the borehole installations on weekly intervals since completion of the fieldwork. The results of this monitoring are presented in Appendix F.

The results of the gas monitoring have been compared to figures given in Tables 28, 29 and 30 of CIRIA Report No 149, 'Protecting Development from Methane'.

Methane was encountered at levels up to 0.9% by volume. This corresponds to 'Characteristic Situation 2' in Table 28. Levels of carbon dioxide, up to 3.6% by volume were encountered. These also correspond to 'Characteristic Situation 2'.

These conditions require developments in this area to include ventilation of confined spaces within buildings, well-constructed ground slab, low-permeability gas membrane and minimum penetration of ground slab by services.

6.2.5 Geotechnical Assessment

It is likely that a large 'shed' like structure would be erected in this area. For the purpose of this assessment it is assumed that any development would be a portal fronted structure with column loads supported on pads and wall loads on strips. The following assessment is based on a review of the exploratory hole logs.

Selected samples were scheduled by Parkman for geotechnical testing, comprising; Multistage Triaxials, Oedometer, Atterberg limits, sieve analysis, sedimentation, moisture content, undrained consolidation and permeability tests.

Generally in areas of shallow made ground, (approximately 1m thick), a combination of pads with a net bearing capacity of 130kPa and strips/trench fill with a net bearing capacity of 105kPa could be used.

Areas of deeper made ground (greater than 3m thick) would not be suitable for pads and strip foundations, and piles or ground treatment would need to be considered.

However, the allowable differential settlement should be considered. If low tolerances of settlement are required, it may be necessary to pile or use ground treatment across the whole of Area 1.

In addition the coal mining report has indicated that coal seams are present close to the surface, although there are no recorded entrances on the site, these seams may have been worked historically. Site works proved at least 20m of stiff glacial till. In addition anecdotal information from Ove Arups indicated that rock head would be located at approximately 30m in this area of Manchester. Based on this information it is considered unlikely that any measures would be required to treat mine workings at this site.

6.3 Area 2

Phase 1 of the investigation of Area 2 comprised eight machine excavated trial pits (TP22, TP23, TP25, TP27 to TP31) and six cable percussive boreholes (BH4, BH5, BH6, BH7, BH10, BH11). Phase 2 comprised ten machine excavated trial pits (TP2/1 to TP2/10) and two cable percussive boreholes (BH14 and BH15). The two tables below identify the boreholes, the proven depth of made ground and glacial till, together with brief details of the standpipe installations. Following reassessment of the site boundary by English Partnerships, BH4 and TP31 were no longer included within the study area.

Borehole No.	**Made Ground:**	**Glacial Till:**	**Standpipe response zone:**	**Response Zone Target**
	m AOD			
BH5	69.46 – 64.96	64.96 – >54.96	60.96 – 55.46	Glacial Till
BH6	70.75 – 69.65	69.65 - >62.75	69.25 – 63.75	Glacial Till
BH7	67.80 – 64.80	64.50 – >62.25	69.75 – 64.5	Made Ground
BH10	70.82 – 65.32	65.32 – >62.32	67.82 – 65.32	Made Ground
BH11	70.55 – 64.45	64.45 – >61.55	68.45 – 64.45	Made Ground

Table 4. Phase 1 Borehole and standpipe details

Borehole No.	**Made Ground:**	**Glacial Till:**	**Sand and Gravel**	**Rock**	**Standpipe response zone:**	**Response Zone Target**
	m AOD					
BH14	68.15 – 64.95	64.95 – 53.15	N/A	N/A	54.15 – 57.15	Glacial Till
BH15	68.57 – 66.07	66.07 – 50.07	50.07 – 39.57	39.57 – 37.57	50.07 – 39.07	Sands and Gravels

Table 5. Phase 2 Borehole and standpipe details

6.3.1 Made Ground

Made ground was encountered in each exploratory hole within Area 2 and varied in thickness from approximately 1.00m in borehole BH6 at the south east corner, up to approximately 6.00m thick in borehole BH11. From Phase 1, natural ground was encountered at 1.00m and 2.40m bgl in trial pits TP25 and TP27 respectively. The remaining trial pits encountered at least 4.30m depth of made ground.

During Phase 2, natural ground was encountered between 2.10 and 5.50m depth. Only TP2/3, which terminated at 5.40m depth did not encounter natural ground.

The made ground can be subdivided into two main types;

Granular ashy fill, generally comprising loose dark grey and brown clayey very gravelly SAND with occasional soft clay pockets, occasionally tending to sandy GRAVEL. Gravel is generally sandstone, mudstone, quartz, brick, metal, ash, clinker, ceramic, glass and timber. Occasional cobbles of brick, sandstone and clinker were encountered. TP2/9 encountered a layer of welded slag between 2.00 to 2.40m depth.

Cohesive reworked glacial till, generally comprising both soft to stiff brown and light grey slightly sandy slightly gravelly CLAY with occasional cobbles of sandstone and brick. Gravel is generally coal, mudstone, sandstone, quartz, ash, clinker, glass and brick.

Boreholes BH10 and BH11 and trial pits TP22 and TP23 were located to target the recently backfilled former reservoir in the south eastern corner of Area 2 and encountered made ground to a depth of approximately 6.00m. The base of the made ground was not encountered in TP22 and TP23. This reservoir appears to have been generally backfilled with soft cohesive made ground.

Boreholes BH5, BH14 and BH15 and trial pits TP 27, 29, 30 and TP2/1 to 2/10 were located to target the backfilled former clay pit, beneath the former cricket pitch area. Trial pits TP27, 2/1, 2/2 and 2/4 to 2/10 and borehole BH5 encountered natural Glacial Till at between 2.10 and 5.50m depth. Trial pits TP29, 30 and 2/3 encountered at least 5.40m depth of made ground. Both types of made ground were encountered within the backfilled former clay pit.

Borehole BH4 and trial pits TP 31 and TP 28 were located to target the area of the football pitch and bowling green. Borehole BH4 encountered made ground to a depth of 5.60m, while trial pits TP28 and TP31 encountered made ground to the base of the pits at 2.40m and 4.00m respectively. Both granular and cohesive made ground were encountered within the raised area of the football pitch and bowling green. Subsequent to completion of Phase 1 of the investigation, the football pitch and bowling green and the respective car parks were removed from the study area.

Anecdotal information from Weir Pumps employees on site suggest the raised area of the football pitch and bowling green was constructed through dumping of excavated material from the construction of the foundry. Historically, following construction of the new foundry, waste materials were dumped either side of the main entrance road, at the location of the football pitch and backfilled clay pit.

6.3.2 Glacial Till

Glacial till, where encountered, generally comprised firm, becoming stiff and very stiff with depth, brown, mottled blue grey sandy gravelly CLAY, with occasional cobbles of sandstone. Gravel is quartz, mudstone, coal and carbonaceous mudstone.

A medium dense SAND band was encountered in BH5 from approximately 10.50 to 11.60m depth.

Borehole BH15 encountered light brown medium dense sand from 18.50 to 26.50m depth. From 26.50 to 29.00m depth sand and gravel and gravelly sand was encountered. Weathered mudstone was encountered at 29.00m depth until the termination of the borehole at 30.50m.

6.3.3 Groundwater

Exploratory Hole	Depth of Water Strike m AOD	Strata
TP27	66.24	Made ground
TP29	67.13	Made ground
TP31	67.50	Made ground
BH5	67.96	Made ground
BH7	65.60	Made ground
BH10	67.82	Made ground
TP2/1	67.11	Made ground
TP2/3	66.30	Made ground
TP2/4	66.23	Made ground
TP2/5	67.66	Made ground
TP2/6	66.29	Made ground
TP2/7	67.05	Made ground
TP2/8	67.22, 67.02, 61.12	Made ground
TP2/9	65.87	Made ground
TP2/10	65.67	Made ground
TP25	65.98	Glacial till
BH5	59.96	Glacial till
TP2/2	66.95	Glacial till

Table 6. Groundwater strikes during site works

Both GIP and Soil Mechanics monitored groundwater levels on four occasions since completion of their respective phases of fieldwork. Soil Mechanics were instructed to monitor all boreholes including those excavated by GIP. The results are shown in Table 7 below, with values in m bgl.

Borehole	Response Zone Target	29th Nov 2002	5th Dec 2002	12th Dec 2002	18th Dec 2002	3rd April 2003	25th April 2003	7th May 2003	30th May 2003	4th June 2003
		Depth to water (m AOD)								
BH5	Glacial Till	GIP unable to remove bung		67.21	67.16	67.76	67.43	67.78	68.12	67.94
BH6	Glacial Till	69.89	69.65	69.70	69.80	69.80	68.89	70.12	69.83	69.78
BH7	Made Ground	65.57	65.45	65.50	65.50	65.27	65.14	65.39	65.53	65.53
BH10	Made Ground	68.64	68.82	68.82	68.82	**	68.36	68.68	69.96	68.56
BH11	Made Ground	*	69.35	69.35	69.35	**	68.85	68.96	***	***
BH14	Glacial Till	N/A				60.99	65.07	67.35	67.52	67.33
BH15	Sands and Gravels	N/A				46.21	46.19	46.28	45.61	46.31

Table 7. Groundwater monitoring results – after completion of site works

* Borehole not complete when readings taken
** Readings not taken
*** Borehole covered by rubble

A complete set of water samples were taken from the borehole installations for chemical analysis, following completion of both Phase 1 and Phase 2. These results are discussed in Section 6.3.

6.3.4 Soil Gas

Soil gas levels have been monitored in the borehole installations on weekly intervals since completion of the fieldwork. The results of this monitoring are presented in the table in Appendix F.

The results of the gas monitoring have been compared to figures given in Tables 28, 29 and 30 of CIRIA Report No 149, 'Protecting Development from Methane'.

Methane was encountered in boreholes BH10 and BH11 up to 0.8% by volume. This level of methane corresponds to 'Characteristic Situation 2' in Table 28. The same boreholes encountered levels of carbon dioxide up to 0.6% by volume. This correspond to 'Characteristic Situation 1'. These positions are located on the backfilled reservoir area.

In BH5 and BH6, methane was not detected and carbon dioxide was encountered up to 4.2% by volume. These levels of methane and carbon dioxide correspond to 'Characteristic Situation 2' in Table 28.

Methane was not encountered in BH7. However, carbon dioxide was detected at levels up to 9.5% by volume. This level corresponds to 'Characteristic Situation 4'.

These conditions would therefore require developments in this area to include ventilation of confined spaces within buildings, well-constructed ground slab, low-permeability gas membrane and minimum penetration of ground slab by services (Characteristic Situations 2 and 4) and passive in-ground venting and active venting to building (Characteristic Situation 4 only).

6.4 Area 3

The investigation of Area 3 comprised three machine excavated trial pits (TP32, TP33 and TP34) and two cable percussive boreholes (BH8 and BH9). Table 8 below identifies the boreholes and the proven depth of made ground and glacial till, together with brief details of the standpipe installations.

Borehole No.	Made Ground: m AOD	Glacial Till: m AOD	Standpipe response zone: m AOD	Response Zone Target
BH8	65.22 – 63.42	63.42 – 53.22	63.22 – 54.22	Glacial Till
BH9	68.79 – 67.29	67.29 – 60.29	67.29 – 61.29	Glacial Till

Table 8. Borehole and standpipe details

6.4.1 Made ground

The thickness of made ground was variable across Area 3, from 0.25m thick in TP34 to 1.80m thick in BH8. Generally thicker made ground was encountered towards the middle of the area. In general it comprised granular ashy material and cohesive material, commonly reworked glacial till. In general the granular made ground is found above the cohesive made ground. However, both types of made ground were not always encountered, cohesive being absent from TP32 and TP34.

Granular made ground generally comprised loose gravelly SAND or sandy GRAVEL, being clayey in places. The gravel generally comprised ash, clinker and brick. Cobbles of brick were encountered in TP32, and of sandstone in BH8.

Cohesive made ground generally comprised firm and stiff, in places soft, sandy gravelly CLAY. The gravel is commonly ash, slag, coal, brick, limestone and mudstone. Cobbles of sandstone were encountered in BH8.

6.4.2 Natural Glacial Till

Glacial till, generally comprising stiff, becoming very stiff brown, mottled light blue slightly sandy slightly gravelly clay was encountered beneath the made ground. Gravel comprised sandstone, quartz, mudstone and coal. Occasional cobbles of quartz were encountered in BH8. Occasional sand pockets were encountered in TP34.

6.4.3 Groundwater

Groundwater was not encountered during site works in any of the trial pits or boreholes.

Monitoring of water levels in all of the borehole installations was carried out by GIP on four occasions. Soil Mechanics were instructed to monitor all boreholes on an additional four occasions. The results of this monitoring are shown in Table 9 below, with values in m AOD.

Borehole	**Response Zone Target**	**29th Dec 02**	**5th Dec 02**	**12th Dec 02**	**18th Dec 02**	**3rd April 03**	**25th April 03**	**7th May 03**	**30th May 03**	**4th June 03**
		Elevation of groundwater (m AOD)								
BH8	Glacial Till	64.62	64.22	64.22	64.22	63.87	*	64.27	64.36	64.47
BH9	Glacial Till	68.29	68.19	68.09	68.04	68.41	*	68.39	67.77	67.72

Table 9. Groundwater monitoring results, after completion of site works

* Levels were taken but the results were lost by Soil Mechanics

A complete set of water samples were taken from the borehole installations for chemical analysis. These results are discussed in Section 6.3.

6.4.4 Soil Gas

Soil gas levels have been monitored in the borehole installations on weekly intervals since completion of the fieldwork. The results of this monitoring are presented in the table in Appendix F.

The results of the gas monitoring have been compared to figures given in Tables 28,29 and 30 of CIRIA Report No 149, 'Protecting Development from Methane'.

Methane was not encountered in either of the two boreholes. This corresponds to 'Characteristic Situation 1' in Table 28. Levels of carbon dioxide, up to 1.3% by volume were encountered. These also correspond to 'Characteristic Situation 1'.

These conditions require developments in this area to include no special precautions.

6.5 Area 4

The investigation of Area 4 comprised nine machine excavated trial pits (TP37 – TP45) and two cable percussive boreholes (BH12 and BH13). Table 10 below identifies the boreholes and the proven depth of made ground and glacial till, together with brief details of the standpipe installations.

Borehole No.	Made Ground:	Glacial Till:	Sand and/or Gravel	Rock	Standpipe response zone:	Response Zone Target
	m AOD					
BH12	70.69 - 69.19	69.19 - 55.69	64.49 – 64.19	N/A	65.69 - 63.69	Glacial Till inc sand layer
BH13	73.12 - 71.12	71.12 - 46.12	46.12 – 45.12	N/A	45.12 - 46.12	Glacial Sand

Table 10. Borehole and standpipe details

6.5.1 Made Ground

The thickness of made ground was relatively uniform across Area 4, from 1.00m in TP40 to at least 4.00m depth in TP38. The thickness was generally between 2.00 to 2.50m. The deeper made ground was encountered in the north east corner around TP38, the area formerly occupied by buildings. In general, the made ground comprised granular ashy material and cohesive material, commonly reworked glacial till. In general the granular fill is found above the cohesive fill.

Granular made ground generally comprised loose gravelly SAND or sandy GRAVEL, being silty or clayey, with occasional cobbles in places. The gravel generally comprised ash, clinker, brick, ceramics and concrete. Cobbles are generally brick and concrete.

Cohesive made ground generally comprised firm and stiff sandy, gravelly CLAY. Gravels include ash, clinker, brick, wood, siltstone and sandstone.

6.5.2 Glacial Till

Glacial till, generally comprising stiff, becoming very stiff brown, occasionally mottled grey slightly sandy slightly gravelly clay, with some silt laminae was encountered beneath the made ground. Gravel comprised mudstone, siltstone, sandstone and coal. Occasional centimetre sized fine sand lenses encountered in TP45.

A light brown SAND was encountered in BH13 from 27.00 to 28.00m. It is likely that sand bands, if laterally extensive may provide a pathway for migration of groundwater and contaminants across and away from the site.

6.5.3 Groundwater

Exploratory Hole	Depth of Water Strike m AOD	Strata	Notes
TP37	1.10 (bgl)	Made ground	
TP38	73.17 – 71.77	Made ground	
TP42	71.44 – 71.9	Made ground	
TP43	72.10	Made ground	
TP44	73.42 and 72.37	Made ground	
TP45	72.30	Made ground	
BH12	64.49	Glacial till	Rose to 64.99 after 20 minutes

Table 11. Groundwater monitoring results, during site works

Soil Mechanics monitored groundwater levels on four occasions since completion of the fieldwork. The results are shown in the table below, with values in m AOD.

Borehole	**Response Zone Target**	**3rd April 03**	**25th April 03**	**7th May 03**	**30th May 03**	**4th June 03**
		Elevation of groundwater (m AOD)				
BH12	Glacial Till	68.81	*	68.94	68.90	69.02
BH13	Glacial Sand and Gravel	56.12	*	48.84	48.81	49.00

Table 12. Groundwater monitoring results, after completion of site works

* Readings taken, but misplaced by Soil Mechanics.

A complete set of water samples were taken from the borehole installations for chemical analysis. These results are discussed in Section 6.3.

6.5.4 Soil Gas

Soil gas levels have been monitored in the borehole installations on weekly intervals since completion of the fieldwork. The results of this monitoring are presented in the table in Appendix F.

The results of the gas monitoring have been compared to figures given in Tables 28,29 and 30 of CIRIA Report No 149, 'Protecting Development from Methane'.

Methane was encountered in BH13 at levels up to 0.4%. This corresponds to 'Characteristic Situation 2' in Table 28. Levels of carbon dioxide, up to 0.6% by volume were encountered. This corresponds to 'Characteristic Situation 2'.

These conditions require developments in this area to include ventilation of confined spaces within buildings, well-constructed ground slab, low-permeability gas membrane and minimum penetration of ground slab by services.

6.6 Groundwater Regime

From the groundwater monitoring information and readings taken during site works it is apparent that there are three groundwater phases at the site:

- perched water is present within the made ground and at the made ground / glacial till interface;
- sand lenses within the Glacial Till;
- groundwater within the bedrock, which may be in hydraulic continuity with sands at the base of the Glacial Till.

Plots of piezometric head across the site, derived from two monitoring visits carried out by Soil Mechanics are presented in Appendix H. They indicate that groundwater flow is towards the south west part of the site.

SECTION 7: CHEMICAL GROUND CONDITIONS

Approximately two chemical samples per exploratory hole were analysed for a standard metals and inorganics suite, including water soluble sulphate to BRE SD1 and speciated polyaromatic hydrocarbons (PAH). One sample per exploratory hole was tested for diesel range organics (DRO), petroleum range organics (PRO), loss on ignition (LOI) and screened for asbestos. In addition a number of samples were tested for ferrous iron and manganese, TPHCWG (Total Petroleum Hydrocarbons Criteria Working Group) and fraction of organic carbon (FOC), (only in samples believed to be free from hydrocarbon contamination). Selected samples were tested for polychlorinated biphenyls (PCBs) where it was believed transformers were located on site. For human health, the results have been compared against applicable 'generic guidelines'. Separate screenings have been made for boron, copper and zinc, for potential impact on plants.

Leachate and water samples were tested for the same basic suite (apart from asbestos and FOC). The leachate samples from each area were selected to cover both types of made ground, with a limited number from the glacial till.

It is assumed that the site will be redeveloped for an industrial / commercial end-use rather than the more sensitive residential end-use.

Figures 4, 5, 6 and 7 summarise the contamination present across each of the four Areas and should be viewed in conjunction with the sections below. It should be noted that removal of the hotspots does not necessarily address the contamination issues across the site. The quantitative groundwater risk assessment is based on a statistical analysis of the results.

In order to assess the significance of contaminants found within the site, the results have been compared against the guidance levels outlined below. All laboratory test results associated with the investigation are included in the GIP factual report, presented in Appendix A and the Soil Mechanics factual report, presented in Appendix B.

7.1 Soil Guideline Values for Human Health

The method by which soils are assessed with respect to contamination has changed from the ICRCL guidance, used for some 20 years, to the 'Contaminated Land Exposure Assessment' (CLEA) guidance. With the introduction of CLEA, it is now necessary to consider chemical soil concentrations with respect to CLEA Soil Guideline Values (SGV's). SGV's have been introduced for a number of chemical determinants, but not yet for all. Of particular note is that no SGV's have yet been provided for hydrocarbons.

As far as possible, chemical test results have been considered in accordance with the new CLEA guidance.

The CLEA model assesses risks presented by material present within the upper 1m of the soil at the finished development. For this reason, only samples from shallower than 1m or samples which are within strata which is present less than 1m from ground level have been assessed against CLEA guideline values.

In order to compare the concentrations of chemical determinants present on-site with the CLEA SGV's, a 'mean value' test is undertaken. It is necessary to first ascertain the mean concentration of these determinants over the areas with a similar site history and materials, which are similar in nature. A simple arithmetic mean (95% UCL) of the values is calculated. This statistical mean is then compared with the relevant SGV for the redevelopment, which is taken to be industrial end use. This comparison assesses whether the contamination levels present statistically exceed the level where the contaminants might be considered to present a risk to site users.

A 'maximum value' test is performed on values that exceed the SGV to determine if a single elevated value could be considered as an outlier value (i.e. not being representative of the soil as a whole). The 'maximum value' test uses logarithmic measured values. This presents the results in a more or less symmetric distribution that is usually close enough to allow normal statistics to be used with confidence. The data is entered into a formula and if the result is greater than the critical value, the maximum value is treated as an outlier and warrants further investigation as it may indicate a localised area of contamination.

For the purposes of assessing the level of contamination for human health, (for which CLEA was derived) for the chemical determinants that as yet have no SGV's, the results have been compared against professional judgement values. These professional judgement screening values are considered to be health conservative and have been derived for use as screening values only. They have not been derived to form remediation criteria values. If there is an exceedence of any of these values, then further work should be undertaken to assess the likely impact on human health.

The limit of detection for PCBs is 0.001mg/kg for the seven Aroclors for the phase 1 results. This has been taken as the trigger level as it is felt that if PCBs are present in any concentration greater than the detection limit, then further work should be carried out to assess the likely impact to human health. PCBs were not tested for during phase 2 as no potential sources were identified.

Trigger Values of 1000mg/kg for DRO, 82mg/kg for PRO, 2000mg/kg for TPHCWG and 25mg/kg for PAH were determined by professional judgement.

In order to assess the speciated PAH values, the results were converted to an equivalence of Benzo (a) Pyrene, (BaP) the most carcinogenic PAH, using the published toxicological data. Any values greater than 25mg/kg were considered significant.

Table 13, below identifies contaminants analysed for, and the adopted guideline value and its derivation, for human health. Table 14 indicates the screening values for phytotoxic contaminants.

Soil Contaminant	Site Threshold Value (STV) mg/kg	Basis of STV
Arsenic	500	CLEA Soil Guideline Value (SGV) for commercial/industrial end use
Cadmium	1400	CLEA Soil Guideline Value (SGV) for commercial/industrial end use (all pH values)
Chromium	5000	CLEA Soil Guideline Value (SGV) for commercial/industrial end use (assumes Cr VI)
Lead	750	CLEA Soil Guideline Value (SGV) for commercial/industrial end use
Mercury	480	CLEA Soil Guideline Value (SGV) for commercial/industrial end use
Nickel	5000	CLEA Soil Guideline Value (SGV) for commercial/industrial end use
Selenium	8000	CLEA Soil Guideline Value (SGV) for commercial/industrial end use
Cyanide – Total	250	Professional Judgement
Phenols (Total)	5	Professional Judgement
Sulphide	250	Professional Judgement
pH	<5.5 and >10	Professional Judgement (looking at acid and alkaline conditions
Diesel Range Organics (DRO)	1000	Professional Judgement
Petroleum Range Organics (PRO)	82	Professional Judgement
Speciated Polyaromatic Hydrocarbons – PAH. Converted to BaP equivalence	25	Professional judgement based on toxicity information
Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG)	2000	Professional Judgement

Table 13. Summary of contaminants and associated screening values for human health

In addition, selected samples were analysed for:

Soil Contaminant:	Site Threshold Value (STV) mg/kg	Basis of STV
Polychlorinated Biphenyl (PCB)	0.01	Professional Judgement. SAV = Limit of Detection
Water Soluble Sulphate to BRE SD1	-	Concrete in aggressive ground BRE Special Digest 1
Asbestos	Presence	-

Table 14. Additional contaminants and associated screening values for human health.

The FOC, ferrous iron, manganese and LOI testing was scheduled for use in the detailed risk assessment.

7.2 Soil Guideline Values for Phytotoxic Contaminants

In order to assess the potential effect of boron, copper and zinc on plant growth the ICRCL guideline values from ICRCL 59/83 'Guidance on the Assessment and Redevelopment of Contaminated Land' 2nd Edition (1987) Table 3, Group B are used.

These ICRCL values were originally specifically derived for the phytotoxic elements. As with the screening of soils for human health, only samples from shallower than 1m or samples which are within strata which is present less than 1m from ground level have been assessed against the phytotoxic screening values.

Table 15 below indicates the adopted guideline values and their derivation for phytotoxic elements.

Soil Contaminant:	Site Threshold Value (STV) mg/kg	Basis of STV
Boron	3	ICRCL – Table 3, Group B
Copper	130	ICRCL – Table 3, Group B
Zinc	300	ICRCL – Table 3, Group B

Table 15. Summary of phytotoxic contaminants and their screening values

7.3 Water and Leachate Screening

Chemical test results for groundwater and leachate have been compared against the Environment Agency's Environmental Quality Standard (EQS), and where no EQS value exists, against maximum allowable concentrations (MAC) from the UK Water Supply (Water Quality) Regulations 1989.

Determinant	Site Threshold Value (STV) mg/l	Basis of STV
Arsenic	0.05	EQS
Boron	2	EQS
Cadmium	0.005	EQS
Chromium	0.05	EQS
Copper	3	UKDW
Lead	0.05	EQS
Mercury	0.001	EQS
Nickel	0.05	EQS
Selenium	0.01	EQS
Zinc	5	EQS
Cyanide - Total	0.05	UKDW
Cyanide (Free)	0.05	UKDW
Phenols (Total)	0.0005	UKDW
Total Sulphur as SO_4	250	EQS
pH	<5.5, >9.5	EQS
Petroleum Range Organics (PRO)	0.01	Professional Judgement based on UKDW for mineral oils
Diesel Range Organics (DRO)	0.01	Professional Judgement based on UKDW for mineral oils
Speciated Polyaromatic Hydrocarbons – PAH. Converted to BaP equivalence	0.0002	UKDW
Polychlorinated Biphenyl (PCB)	0.001	Professional Judgement based on Limit of Detection

Table 16. Summary of contaminants and associated screening values for water and leachate.

7.4 Made Ground

In order to assess the significance of contaminants found within the site, the results have been compared against the guidance levels outlined above. All laboratory test results associated with the investigation are included in the GIP and Soil Mechanics factual reports, presented in Appendices A and B.

The following sections summarise the results of the screening for each soil type from each area of the site and should be read in conjunction with Appendix G, which provides the detailed results and the CLEA statistical analysis of the soil test results.

The Made Ground was generally similar across the whole site comprising two types, granular and cohesive. Given the different histories of the four areas for the purposes of statistical analysis the results for the made ground have been assessed for each Area and for both types of material.

Asbestos was not detected in any of the samples for which it was tested.

7.4.1 Area 1 Screening for Human Health

Seventeen samples of the granular made ground and twenty-two samples of cohesive made ground were tested from across Area 1. Results from PB Kennedy and Donkin were not used for this area of the site as ground works following demolition of the machine shed has reworked the made ground.

Tables 17 and 18 below summarise the human health screening for the granular and cohesive made ground carried out as part of the CLEA modelling. The information in the tables is a summary of the results of the example mean and max value tests found in Appendix G. Figure 4 summarises the outliers identified in the tables below for Area 1.

In addition, one sample from the granular made ground recorded a PCB concentration greater than the limit of detection - TP13 at 0.30m (2.576mg/kg) and one sample from the cohesive made ground recorded a PCB concentration greater than the limit of detection - TP12 at 0.40m (8.493mg/kg).

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	3.00-37.00	19.42	500	No	No	Average concentration less than STV, no hotspots
Cadmium	1.00-2.00	1.26	1400	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Chromium	9.00-105.00	42.53	5000	No	No	Average concentration less than STV, no hotspots
Lead	38.00-1128.00	453.00	750	No	No	Average concentration less than STV, no hotspots
Mercury	1.00-13.00	2.94	480	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Nickel	9.00-47.00	30.90	5000	No	No	Average concentration less than STV, no hotspots
Selenium	1.00	1.00	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	2.50-47.80	9.82	250	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Phenols	0.01-0.58	0.13	5	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Sulphide	5.00-39.00	14.25	250	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
pH	7.07-9.09	8.18	10	No	No	Average concentration less than STV, no hotspots
PRO	0.01-3.38	1.10	82	No	No	Average concentration less than STV, no hotspots
DRO	74.00-6072.00	2205.31	1000	Yes	No	Average concentration greater than STV
PAH	0.16-58.22	22.94	25	No	No	Average concentration less than STV, no hotspots

Table 17. Summary of hotspot analysis of Area 1 Granular Made Ground

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	1.00-21.00	8.80	500	No	No	Average concentration less than STV, no hotspots
Cadmium	1.00-7.00	1.79	1400	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Chromium	13.00-122.00	37.2	5000	No	No	Average concentration less than STV, no hotspots
Lead	8.00-286.00	144.61	750	No	No	Average concentration less than STV, no hotspots
Mercury	1.00	1.00	480	No	No	Average concentration less than STV, no hotspots
Nickel	13.00-79.00	26.73	5000	No	No	Average concentration less than STV, no hotspots
Selenium	1.00-2.00	1.12	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	2.50-3.00	2.50	250	No	No	Average concentration less than STV, no hotspots
Phenols	0.01-0.17	0.04	5	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Sulphide	5.00-152.00	28.00	250	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
pH	6.55-8.96	8.20	10	No	No	Average concentration less than STV, no hotspots
PRO	0.01-0.98	0.39	82	No	No	Average concentration less than STV, no hotspots
DRO	19.00-816.00	491.21	1000	No	No	Average concentration less than STV, no hotspots
PAH	0.03-17.30	6.82	25	No	No	Average concentration less than STV, no hotspots

Table 18. Summary of hotspot analysis of Area 1 Cohesive Made Ground

7.4.2 *Area 1 Screening For Phytotoxic Contaminants*

Tables 19 and 20 below summarise the phytotoxic screening for the granular and cohesive made ground. The information in the tables is a summary of the results of the example mean and max value tests found in Appendix G. Figure 4 summarises the outliers identified in the tables below for Area 1.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Boron	1.00-3.00	1.90	3	No	No	Average concentration less than STV, no hotspots
Copper	16.00-421.00	177.95	130	Yes	No	**Average concentration greater than STV**
Zinc	109.00-1461.00	517.15	300	Yes	No	**Average concentration greater than STV**

Table 19. Summary of phytotoxic hotspot analysis of granular made ground Area 1.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Boron	1.00-4.00	1.63	3	No	Yes	**Average concentration less than STV, hotspot present TP12 @ 0.4m bgl**
Copper	19.00-590.00	159.69	130	**Yes**	No	**Average concentration greater than STV**
Zinc	41.00-1146.00	250.28	300	No	**Yes**	**Average concentration less than STV, hotspot present TP12 @ 0.4m bgl**

Table 20. Summary of phytotoxic hotspot analysis of cohesive made ground Area 1.

7.4.3 Area 2 Screening for Human Health

Fifteen samples of the granular made ground and seventeen samples of clayey made ground were tested from across this area. These results were combined with the results from an additional nine granular made ground samples and eight additional cohesive made ground samples from PB Kennedy and Donkin. Subsequent to completion of the fieldwork, the Football Pitch and Bowling Green were removed from the study area. All the CLEA modelling has been carried out including samples from BH4, TP28 and TP31. Samples from these three exploratory holes do not significantly alter the statistical results.

Tables 21 and 22 below summarise the human health screening for the granular and cohesive made ground carried out as part of the CLEA modelling. The information in the tables is a summary of the results of the example mean and max value tests found in Appendix G. Figure 5 summarises the outliers identified in the tables below for Area 2.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	5.00-80.30	44.73	500	No	No	Average concentration less than STV, no hotspots
Cadmium	0.23-4.00	1.41	1400	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Chromium	11.40-100.00	44.09	5000	No	No	Average concentration less than STV, no hotspots
Lead	56.00-805.00	317.16	750	No	No	Average concentration less than STV, no hotspots
Mercury	0.17-2.46	1.00	480	No	No	Average concentration less than STV, no hotspots
Nickel	20.00-99.00	55.50	5000	No	No	Average concentration less than STV, no hotspots
Selenium	0.50-1.40	1.03	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	1.00-5.80	2.28	250	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Phenols	0.01-2.50	1.33	5	No	No	Average concentration less than STV, no hotspots
Sulphide	2.00-28.00	12.19	250	No	No	Average concentration less than STV, no hotspots
pH	5.10-8.70	7.82	10	No	No	Average concentration less than STV, no hotspots
PRO	0.20	Insufficient sample number to run the statistical analysis accurately				
DRO	155.00	Insufficient sample number to run the statistical analysis accurately				
BAP	0.64-25.36	12.67	25	No	No	Average concentration less than STV, no hotspots
TPH	298.00	Insufficient sample number to run the statistical analysis accurately				

Table 21. Summary of hotspot analysis of Area 2 Granular Made Ground

Determinand	Range detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	2.00-29.40	14.81	500	No	No	Average concentration less than STV, no hotspots
Cadmium	0.16-2.00	1.10	1400	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Chromium	16.40-58.00	35.33	5000	No	No	Average concentration less than STV, no hotspots
Lead	21.00-465.00	188.73	750	No	No	Average concentration less than STV, no hotspots
Mercury	0.11-5.30	1.51	480	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Nickel	16.00-46.00	33.37	5000	No	No	Average concentration less than STV, no hotspots
Selenium	0.50-2.00	1.05	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	1.00-3.00	2.33	250	No	No	Average concentration less than STV, no hotspots
Phenols	0.01-4.70	1.16	5	No	No	Average concentration less than STV, no hotspots
Sulphide	2.00-57.00	22.72	250	No	No	Average concentration less than STV, no hotspots
pH	7.30-8.97	8.19	10	No	No	Average concentration less than STV, no hotspots
PRO	No samples tested from less than 1.0m depth.					
DRO	No samples tested from less than 1.0m depth.					
PAH	0.53-38.45	19.58	25	No	No	Average concentration less than STV, no hotspots
TPH	46.00-507.00	1731.82	1000	No	No	Average concentration less than STV, no hotspots

Table 22. Summary of hotspot analysis of Area 2 Cohesive Made Ground

7.4.4 Area 2 Screening for Phytotoxic Contaminants

Tables 23 and 24 below summarise the phytotoxic screening for the granular and cohesive made ground. The information in the tables is a summary of the results of the example mean and max value tests found in Appendix G. Figure 5 summarises the outliers identified for Area 2 in the tables below.

Determinand	**Range Detected (mg/kg)**	**95% upper bound (ppm)**	**STV ppm**	**95% UB > STV?**	**Outliers detected?**	**Comment**
Boron	0.50-2.20	1.12	3	No	No	Average concentration less than STV, no hotspots
Copper	47.70-6328.00	1597.33	130	**Yes**	No	**Average concentration greater than STV**
Zinc	47.30-1291.00	442.82	300	**Yes**	No	**Average concentration greater than STV**

Table 23. Summary of phytotoxic hotspot analysis of granular made ground Area 2.

Determinand	**Range Detected (mg/kg)**	**95% upper bound (ppm)**	**STV ppm**	**95% UB > STV?**	**Outliers detected?**	**Comment**
Boron	0.50-2.00	1.30	3	No	No	Average concentration less than STV, no hotspots
Copper	29.10-329.00	166.57	130	**Yes**	No	**Average concentration greater than STV**
Zinc	46.00-638.00	226.50	300	No	**Yes**	**Average concentration less than STV, hotspot present TP23 @ 0.5m bgl**

Table 24. Summary of phytotoxic hotspot analysis of cohesive made ground Area 2.

7.4.5 Area 3 Screening for Human Health

Four samples of the ashy made ground and two samples of clayey made ground were tested from across this area. These results were combined with the results from an additional four granular made ground samples and one additional cohesive made ground sample from PB Kennedy and Donkin.

Tables 25 and 26 below summarises the human health screening for the granular and cohesive made ground carried out as part of the CLEA modelling. The information in the tables is a summary of the results of the example mean and max value tests found in Appendix G. Figure 6 summarises the outliers identified for Area 3 in the tables below.

Determinand	Range detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	4.00-90.10	55.88	500	No	No	Average concentration less than STV, no hotspots
Cadmium	0.50-1.00	0.97	1400	No	No	Average concentration less than STV, no hotspots
Chromium	7.00-56.00	38.34	5000	No	No	Average concentration less than STV, no hotspots
Lead	7.00-1096.00	557.01	750	No	No	Average concentration less than STV, no hotspots
Mercury	0.50-1.10	1.01	480	No	No	Average concentration less than STV, no hotspots
Nickel	9.00-75.00	57.20	5000	No	No	Average concentration less than STV, no hotspots
Selenium	0.50-2.00	1.55	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	1.00-6.40	3.63	250	No	No	Average concentration less than STV, no hotspots
Phenols	0.01-1.00	0.86	5	No	No	Average concentration less than STV, no hotspots
Sulphide	2.00-10.00	9.07	250	No	No	Average concentration less than STV, no hotspots
pH	7.40-8.50	8.19	10	No	No	Average concentration less than STV, no hotspots
PRO	0.01-0.03	0.03	82	No	No	Average concentration less than STV, no hotspots
DRO	38.00-1346.00	Insufficient sample number to run the statistical analysis accurately				
PAH	0.17-5.45	5.52	25	No	No	Average concentration less than STV, no hotspots

Table 25. Summary of Human Health Screening of Area 3 Granular Made Ground

Determinand	Range detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	4.00-27.30	34.39	500	No	No	Average concentration less than STV, no hotspots
Cadmium	0.50-1.00	1.32	1400	No	No	Average concentration less than STV, no hotspots
Chromium	22.00-98.00	120.57	5000	No	No	Average concentration less than STV, no hotspots
Lead	11.00-139.00	182.57	750	No	No	Average concentration less than STV, no hotspots
Mercury	0.50-1.00	1.32	480	No	No	Average concentration less than STV, no hotspots
Nickel	29.00-63.00	73.16	5000	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Selenium	0.60-2.00	2.42	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	1.00-4.71	5.88	250	No	No	Average concentration less than STV, no hotspots
Phenols	0.01-1.00	1.29	5	No	No	Average concentration less than STV, no hotspots
Sulphide	2.00-10.00	15.11	250	No	No	Average concentration less than STV, no hotspots
pH	6.46-7.97	8.67	10	No	No	Average concentration less than STV, no hotspots
PRO	0.01-0.04	0.10	82	No	No	Average concentration less than STV, no hotspots
DRO	13.00-183.00	634.67	1000	No	No	Average concentration less than STV, no hotspots
PAH	0.09-7.58	Insufficient samples are present to undertake a statistical analysis				

Table 26. Summary of outlier analysis of Area 3 Cohesive Made Ground

7.4.6 Area 3 Screening for Phytotoxic Contaminants

Tables 27 and 28 below summarise the phytotoxic screening for the granular and cohesive made ground. The information in the tables is a summary of the results of the example mean and max value tests found in Appendix G. Figure 6 summarises the outliers identified for Area 3 in the tables below.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Boron	0.50-1.00	0.97	3	No	No	Average concentration less than STV, no hotspots
Copper	22.00-412.00	250.11	130	**Yes**	No	**Average concentration greater than STV**
Zinc	58.00-595.00	370.36	300	**Yes**	No	**Average concentration greater than STV**

Table 27. Summary of phytotoxic screening of granular made ground Area 3.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Boron	1.00-2.00	2.31	3	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Copper	46.00-329.00	412.55	130	**Yes**	No	**Average concentration greater than STV**
Zinc	70.00-111.00	132.66	300	No	No	Average concentration less than STV, no hotspots

Table 28. Summary of phytotoxic screening of cohesive made ground Area 3.

7.4.7 Area 4 Screening for Human Health

Ten samples of ashy made ground and five samples of clayey made ground were tested from across this area.

Table 29 below summarises the human health screening for the granular made ground carried out as part of the CLEA modelling. The information in the table is a summary of the results of the example mean and max value tests found in Appendix G. Figure 7 summarises the outliers identified in the tables below for Area 4. No table is present for the cohesive made ground as only one sample was present from cohesive made ground within the upper metre of soil. This is not enough to carry out the statistical analysis, but no STV exceedences were recorded.

Determinand	Range detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	5.50-48.30	47.05	500	No	No	Average concentration less than STV, no hotspots
Cadmium	0.11-1.02	0.90	1400	No	No	Average concentration less than STV, no hotspots
Chromium	27.10-71.70	67.85	5000	No	No	Average concentration less than STV, no hotspots
Lead	60.50-1140.00	1033.93	750	**Yes**	No	**Average concentration greater than STV**
Mercury	0.10-1.43	1.07	480	No	No	Average concentration less than STV, no hotspots
Nickel	30.90-96.20	78.01	5000	No	No	Average concentration less than STV, no hotspots
Selenium	0.50-1.26	1.16	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	1.00-6.00	4.58	250	No	No	Average concentration less than STV, no hotspots
Phenols	1.20-4.30	3.44	5	No	No	Average concentration less than STV, no hotspots
Sulphide	5.00-33.00	28.18	250	No	No	Average concentration less than STV, no hotspots
pH	8.00-8.50	8.44	10	No	No	Average concentration less than STV, no hotspots
PRO	0.20-0.23	0.22	82	No	Yes	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
DRO	66.00-1170.00	1039.76	1000	**Yes**	No	**Average concentration greater than STV**
PAH	1.20-44.30	29.03	25	**Yes**	**Yes**	**Average concentration greater than STV, hotspot present TP39 @ 0.50m bgl**
TPH	317.00-1980.00	Insufficient sample number to run the statistical analysis accurately				

Table 29. Summary of Human Health Screening of Area 4 Granular Made Ground

7.4.8 Area 4 Screening for Phytotoxic Contaminants

Table 30 below summarises the phytotoxic screening for the granular made ground. The information in the table is a summary of the results of the example mean and max value tests found in Appendix G. Figure 7 summarises the outliers identified for Area 4 in the table below. No table is present for the cohesive made ground as only one sample was present from cohesive made ground within the upper metre of soil. This is not enough to carry out the statistical analysis, but no STV exceedences were recorded.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Boron	1.10-3.50	3.07	3	**Yes**	No	**Average concentration greater than STV**
Copper	85.40-562.80	488.09	130	**Yes**	No	**Average concentration greater than STV**
Zinc	90.70-694.50	573.78	300	**Yes**	No	**Average concentration greater than STV**

Table 30. Summary of phytotoxic screening of granular made ground Area 4.

7.5 Glacial Till

Twenty-five samples of glacial till from across the site were analysed. These results were combined with fourteen glacial till results from the PB Kennedy and Donkin ground investigation.

7.5.1 Screening for human health

Table 31 below summarises the human health hotspot analysis for the glacial till carried out as part of the CLEA modelling. The information in the table is a summary of the results of the example mean and max value tests found in Appendix G. The information is summarised on the relevant hotspot figure for each area.

Determinand	Range Detected (mg/kg)	95% upper bound (ppm)	STV ppm	95% UB > STV?	Outliers detected?	Comment
Arsenic	1.00-94.80	22.74	500	No	No	Average concentration less than STV, no hotspots
Cadmium	0.20-11.70	2.16	1400	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Chromium	16.00-61.00	35.58	5000	No	No	Average concentration less than STV, no hotspots
Lead	5.00-1279.00	298.44	750	No	No	Average concentration less than STV, no hotspots
Mercury	0.50-4.80	1.36	480	No	**Yes**	Average concentration less than STV, outliers present but not considered significant as concentrations significantly less than STV
Nickel	19.00-103.00	45.80	5000	No	**Yes**	Average concentration less than STV, outlier present but not considered significant as concentration significantly less than STV
Selenium	0.50-1.00	0.87	8000	No	No	Average concentration less than STV, no hotspots
Cyanide	1.00-2.80	2.11	250	No	No	Average concentration less than STV, no hotspots
Phenols	0.01-38.00	4.41	5	No	**Yes**	**Average concentration less than STV, hotspot present PBKD TP1 @ 0.7mbgl**
Sulphide	2.00-128.50	20.90	250	No	**Yes**	Average concentration less than STV, outliers present but not considered significant as concentrations significantly less than STV
pH	7.30-10.00	8.47	10	No	**Yes**	Average concentration less than STV, outlier present but not considered significant
PRO	No samples tested from less than 1.0m depth.					
DRO	No samples tested from less than 1.0m depth.					
PAH as BAP	0.04-5.06	2.12	25	No	No	Average concentration less than STV, no hotspots
TPH	No samples tested from less than 1.0m depth. Insufficient sample number to carry out statistical assessment accurately					

Table 31. Summary of hotspot analysis of Glacial Till

7.5.2 Screening for phytotoxic contaminanats

Table 32 below summarises the phytotoxic screening for the glacial till. The information in the table is a summary of the results of the example mean and max value tests found in Appendix G.

Determinand	**Range Detected (mg/kg)**	**95% upper bound (ppm)**	**STV ppm**	**95% UB > STV?**	**Outliers detected?**	**Comment**
Boron	0.50-4.30	1.17	3	No	**Yes**	**Average concentration less than STV, hotspot present PBKD TP4 @ 0.8mbgl**
Copper	2.50-2460.00	205.50	130	**Yes**	**Yes**	**Average concentration greater than STV, and hotspot present PBKD TP1 @ 0.7m bgl**
Zinc	28.10-1483.00	231.90	300	No	**Yes**	**Average concentration less than STV, hotspots present PBKD TP4 @ 0.8mbgl and PBKD TP8 @ 1.25m bgl**

Table 32. Summary of phytotoxic screening of glacial till

7.6 Groundwater

Post fieldwork groundwater monitoring was programmed to be carried out prior to demobilisation and on four occasions at weekly intervals following completion of the fieldwork. Water samples were taken from the borehole installations during the first return monitoring visit for each phase. The results of the chemical testing are presented in the GIP factual report, presented in Appendix A and within the Soil Mechanics factual report presented in Appendix B. Four water samples were taken from the Rochdale Canal during phase 1 and an additional three samples during phase 2.

A number of samples recorded levels elevated with respect to the generic guidelines. It should be noted that the phase 1 laboratory detection limits for total cyanide, free cyanide, DRO and PRO and the phase 2 laboratory detection limit for total cyanide, free cyanide, total phenols and cadmium are all above the relevant UKDW level screening value.

These elevated results can generally be linked to sources identified in previous sections and addressed in the remedial measures below.

7.6.1 Area 1

	Total Cyanide	Phenols	Free Cyanide	DRO	PRO
	0.05mg/l	**0.0005 mg/l**	**0.05mg/l**	**0.01mg/l**	**0.01mg/l**
BH1	0.05 [2]	0.01 [1]	0.05 [2]	0.011	0.01 [2]
BH3	0.05 [2]	0.01 [1]	0.05 [2]	0.016	0.01 [2]

Table 33. Summary of groundwater exceedences within Area 1 from the phase 1 monitoring visit

1: Result is less than limit of detection, but greater than screening value.
2: Limit of detection equals the screening value

	Total Cyanide	Phenols	Free Cyanide	TPH CWG	PAH
	0.05mg/l	**0.0005 mg/l**	**0.05mg/l**	**0.01mg/l**	**0.0002mg/l**
BH1	0.10 [1]	0.35 [1]	0.10 [1]	0.41	0.0022 [1]
BH3	0.10 [1]	0.35 [1]	0.10 [1]	0.10 [1]	0.0022 [1]

Table 34. Summary of groundwater exceedences within Area 1 from the phase 2 monitoring visit

1: Result is less than limit of detection, but greater than screening value

7.6.2 Area 2

	Total Cyanide	Phenols	Free Cyanide	DRO	PRO
	0.05mg/l	**0.0005 mg/l**	**0.05mg/l**	**0.01mg/l**	**0.01mg/l**
BH6	0.05 [2]	0.01 [1]	0.05 [2]	0.017	0.01 [2]
BH7	0.05 [2]	0.01 [1]	0.05 [2]	0.016	0.01 [2]
BH10	0.05 [2]	0.01 [1]	0.05 [2]	0.601	0.01 [2]
BH11	0.05 [2]	0.01 [1]	0.05 [2]	0.032	0.01 [2]

Table 35. Summary of groundwater exceedences within Area 2 from the phase 1 monitoring visit

1: Result is less than limit of detection, but greater than screening value.
2: Limit of detection equals the screening value

	Chromium (VI)	Total Cyanide	Phenols	Free Cyanide	TPH	PAH
	0.05 mg/l	**0.05 mg/l**	**0.0005 mg/l**	**0.05 mg/l**	**0.1 mg/l**	**0.0002 mg/l**
BH5	-	0.10[1]	0.35[1]	0.10[1]	0.21	0.0022[1]
BH6	-	0.10[1]	0.35[1]	0.10[1]	0.10[1]	0.0022[1]
BH7	-	0.10[1]	0.35[1]	0.10[1]	0.10[1]	0.0022[1]
BH10	-	0.10[1]	0.35[1]	0.10[1]	59.3	0.39
BH11	-	0.10[1]	0.35[1]	0.10[1]	3.11	0.0059
BH14	0.06	0.10[1]	0.35[1]	0.10[1]	0.10[1]	0.0022[1]
BH15	-	I.S	0.35[1]	I.S	2.17	I.S

Table 36. Summary of groundwater exceedences within Area 2 from the phase 2 monitoring visit

1. Result is less than limit of detection, but greater than screening value
I.S. Insufficient sample

7.6.3 Area 3

	Total Cyanide	Phenols	Free Cyanide	DRO	PRO
	0.05mg/l	**0.0005 mg/l**	**0.05mg/l**	**0.01mg/l**	**0.01mg/l**
BH8	0.05 [2]	0.01 [1]	0.05 [2]	0.012	0.01 [2]
BH9	0.05 [2]	0.01 [1]	0.05 [2]	0.011	0.01 [2]

Table 37. Summary of groundwater exceedences within Area 3 from the phase 1 monitoring visit

1: Result is less than limit of detection, but greater than screening value.
2: Limit of detection equals the screening value

	Total Cyanide	Phenols	Free Cyanide	TPH CWG	PAH
	0.05 mg/l	**0.0005 mg/l**	**0.05 mg/l**	**0.01 mg/l**	**0.0002 mg/l**
BH8	0.10 [1]	0.35 [1]	0.10 [1]	0.10 [1]	0.00252
BH9	0.10 [1]	0.35 [1]	0.10 [1]	0.10 [1]	0.0022 [1]

Table 38. Summary of groundwater exceedences within Area 3 from the phase 2 monitoring visit
1: Result is less than limit of detection, but greater than screening value.

7.6.4 Area 4

	Chromium	Total Cyanide	Selenium	Phenols	TPH CWG	PAH	Free Cyanide
	0.05 mg/l	**0.05 mg/l**	**0.01 mg/l**	**0.0005 mg/l**	**0.01 mg/l**	**0.0002 mg/l**	**0.05 mg/l**
BH13	0.11	0.10 [1]	0.064	0.35	8.70	0.003	0.1 [1]
BH12	-	0.10 [1]	-	0.35	0.10	0.0022	0.1 [1]

Table 39. Summary of groundwater exceedences within Area 4
Note: 1: Result is less than limit of detection, but greater than screening value.

7.6.5 Canal Results

The determinants elevated above the screening value for samples recovered from the canal during phase 1 of the site works are summarised below.

Both the up stream and down stream results for total phenols and PRO are elevated when compared to the screening values. However the results are all below limit of detection.

The results from the upstream sample for PAH and DRO are elevated when compared to the screening values, but the down stream samples are less than the screening values.

The determinants elevated above the screening value for samples recovered from the canal during phase 2 of the site works are summarised below.

Both the up stream and down stream results from phase 2 for PAH, total phenols, total cyanide, free cyanide and TPH are elevated when compared to the screening values. Only the result for the down stream sample is above the limit of detection.

These results are inconclusive in that the phase 1 results indicate the canal is more contaminated upstream than down stream, but the phase 2 results indicate the canal is slightly more contaminated with PAH down stream than upstream.

7.7 Leachate Conditions

In total thirty-two leachate samples were prepared from representative samples of the soil types encountered on-site, with particular attention paid to areas where contamination was expected or where visual/olfactory evidence of contamination existed.

For phase 1, the laboratory detection limits for total phenols and free cyanide are above the relevant screening level, while the limit of detection for total cyanide, DRO and PRO are equal to the limit of detection.

For phase 2, the laboratory detection limits for free cyanide, total phenols, total cyanide, PAH and TPH were above the relevant screening value.

The tables below highlight the samples with leachate results, in addition to those discussed above which exceed the screening values.

7.7.1 Area 1

Exploratory Hole	DRO (ug/l)	Elevated DRO in soil sample	PRO (ug/l)	Elevated PRO in soil sample	PAH (ug/l)	Elevated PAH in soil sample
TP5 @ 0.9	280.00	**Yes**	-	-	-	-
TP13 at 0.3m	48.00	**Yes**	39.00	No	-	-
TP17 at 0.3m	11.00	No	-	-	3.98	No
TP1 at 1.20m	237.00	**Yes**	-	-	0.35	No
TP12 at 0.10m	37.00	No	-	-	0.61	No
TP20 at 1.30m	19.00	No	-	-	0.44	No
TP10 at 0.05m	20.00	No	-	-	-	No
TP35 at 0.2m	24.00	No	-	-	0.37	No

Table 40. Summary of leachate exceedences within Area 1

7.7.2 Area 2

Exploratory Hole	DRO (ug/l)	Elevated DRO in soil sample	PRO (ug/l)	Elevated PRO in soil sample	PAH (ug/l)	Elevated PAH in soil sample	Chromium (VI) (mg/l)	Elevated Chromium in soil sample	Mercury (mg/l)	Elevated Mercury in soil sample	TPH mg/l	Elevated TPH in soil sample
TP27 at 2.4m	92.00	**Yes**	17.00	No	24.20	**Yes**	-	-	-	-	-	-
TP28 at 2.4m	39.00	**Yes**	334.00	No	2.36	**Yes**	-	-	-	-	-	-
BH7 at 1.50m	-	-	-	-	1.44	No	-	-	-	-	-	-
TP22 at 1.30m	166.00	No	-	-	2.52	No	-	-	-	-	-	-
BH10 at 3.00m	68.00	**Yes**	-	-	5.81	**Yes**	-	-	-	-	-	-
BH11 at 5.00m	-	-	-	-	0.29	No	-	-	-	-	-	-
TP29 at 3.00m	-	-	-	-	1.39	**Yes**	-	-	-	-	-	-
TP2/9 at 2.20m	-	-	-	-	-	-	-	-	0.002	No	-	-
TP2/3 at 0.40m	-	-	-	-	-	-	0.10	No	-	-	0.12	Not tested
TP2/5 at 2.90m	-	-	-	-	-	-	0.05	No	-	-	-	-

Table 41. Summary of leachate exceedences within Area 2

7.7.3 Area 3

Exploratory Hole	DRO (ug/l)	Elevated DRO in soil sample	PAH (ug/l)	Elevated PAH in soil sample
TP34 at 0.10m	22.00	No	0.90	No
BH8 at 0.50m	40.00	**Yes**	1.75	No
BH9 at 2.50m	19.00	Not tested	-	-

Table 42. Summary of leachate exceedences within Area 3

7.7.4 Area 4

Exploratory Hole	Mercury (mg/l)	Elevated mercury in soil sample	TPH (mg/l)	Elevated TPH in soil sample	PAH (ug/l)	Elevated PAH in soil sample
TP38 at 2.20m	0.002	No	1.45	Yes	370.00	No
TP42 at 1.00m	0.002	No	-	-	-	-
TP44 at 1.60m	-	-	3.04	No	818.21	No
BH13 at 1.00m	-	-	-	-	2.88	Yes
TP39 at 0.5m	-	-	0.43	No	-	-
TP45 at 2.00m	-	-	-	-	2.20	No
TP40 at 0.80m	-	-	-	-	15.33	No

Table 43. Summary of leachate exceedences within Area 4

7.7.5 Glacial Till

Exploratory Hole	DRO (ug/l)	Elevated DRO in soil sample	PAH (ug/l)	Elevated PAH in soil sample	Chromium (mg/l)	Elevated Cr in soil sample	Mercury (mg/l)	Elevated Hg in soil sample
TP36 at 1.50m (Area 1)	38.00	No	8.94	No	-	-	-	-
BH2 at 2.50m (Area 2)	18.00	No	10.32	No	-	-	-	-
TP2/9 at 3.20m (Area 2)	-	-	-	-	0.06	No	0.002	No
TP25 at 1.80m (Area 2)	-	-	2.15	No	-	-	-	-
TP32 at 1.20m (Area 3)	-	-	1.33	No	-	-	-	-
TP34 at 1.20m (Area 3)	-	-	1.61	No	-	-	-	-
BH9 at 2.50m (Area 3)	19.00	No	1.49	No	-	-	-	-

Table 44. Summary of leachate exceedences within the Glacial Till

SECTION 8: QUALITATIVE ASSESSMENT

Section 4 above summarises the potential sources, pathways and receptors identified from the previous desk studies and intrusive works carried out at the site.

For there to be a risk of pollution or environmental harm occurring as a result of contamination, all of the following elements must be present.

- Source
- Receptor
- Pathway

If one of these elements is missing then there can be no significant risk. If all are present, then the risk from the resulting pollutant linkage should be assessed and an appropriate remediation strategy developed to address the problems and remove the linkage.

8.1 Sources

8.1.1 Soil Sources

- Risks to Human Health

Made ground across the site is a source of contamination. Diesel Range Organics (DRO) from the made ground record 95 % Upper Bound values in excess of the 1000mg/kg site threshold value (STV) derived by professional judgement. This indicates a site wide problem with DRO. Lead and PAH from Area 4 recorded 95% Upper Bound values greater than the screening values. All these contaminants can be attributed to site wide processes.

PCBs were recorded at elevated concentrations in two trial pits within Area 1. PCBs are particularly toxic to human health and their presence within the location of the former power house on site would suggest further investigative work may be required during redevelopment.

An elevated phenol result was recorded within Area 2 within the glacial till. This is not believed to be a site wide problem and can probably be attributed to processes associated with the bituminous and chrome plating plant.

- Risks to Plant Life

Within the made ground across the site, copper and zinc and to a lesser extend boron recorded concentrations which are toxic to plant life. If redevelopment of the site were to include landscaping, this made ground would be unsuitable for sustaining plant life and a planting medium would have to be provided.

- Risks to Site Infrastucture –

Gas monitoring of the borehole installations following completion of the site works has identified elevated levels of carbon dioxide at a number of locations. The recorded levels indicate that protection measures for the proposed development should be integrated into the design.

An assessment of concrete in aggressive ground following the BRE SD1, indicates a

8.1.2 Leachate Sources

Elevated DRO, PRO and copper concentrations were recorded in leachate samples from made ground. Comparison with the corresponding soil results indicate that in some cases the samples with elevated DRO or copper leachate results also exhibited elevated DRO or copper in the made ground soil samples from which the leachate was taken. None of the samples with elevated PRO leachate results exhibited elevated PRO in the soil samples.

Samples from the glacial till also recorded elevated DRO results but the corresponding soil samples did not exhibit elevated DRO concentrations.

The leachate results indicate that in a number of cases the DRO and copper can be leached from the soils in concentrations exceeding the screening value. There is therefore a possibility that these materials could impact on controlled waters.

8.1.3 Groundwater Sources

- Area 1

DRO contaminated groundwater was recovered from the glacial till in BH1 and BH3 during the phase 1 monitoring visit. BH1 also recorded elevated TPH concentrations in samples recovered during the phase 2 monitoring visit. In addition, the total cyanide, phenols, free cyanide, PRO, PAH and TPH (from BH3) results were all less than the limit of detection. However, the limit of detection is greater than the screening value.

- Area 2

DRO contaminated groundwater was recovered from the glacial till in BH6 and the made ground in BH7 during the phase 1 monitoring visit. In addition, the total cyanide, phenols, free cyanide, and PRO results were all less than the limit of detection. However, the limit of detection is greater than the screening value.

Samples recovered from the glacial till in BH14 recorded elevated chromium (VI) and samples from the glacial sands and gravels in BH15 recorded elevated TPH. In addition, the concentrations of total cyanide from BH14, phenols from BH14 and BH15, free cyanide and TPH and PAH from BH14 were all less than the limit of detection. However, the limit of detection is greater than the screening value.

- Area 3

Samples recovered from the glacial till in BH8 and BH9 during the phase 1 monitoring visit recorded elevated DRO concentrations. Samples recovered from BH9 during the phase 2 monitoring visit recorded elevated PAH concentrations. In addition, the concentrations of total cyanide, phenols, free cyanide, TPH from phase 2, PRO from phase 1 and PAH from BH8 from phase 2 were all less than the limit of detection. However, the limit of detection is greater than the screening value.

- Area 4

Groundwater samples recovered from the glacial sands in BH13 recorded elevated chromium, selenium, phenols, TPH and PAH. In addition, total cyanide and free cyanide recorded concentrations were all less than the limit of detection. However, the limit of detection is greater than the screening value.

Groundwater samples recovered from the glacial till (response zone included a sand lense) recorded elevated phenols and PAH. In addition, total cyanide, TPH and free cyanide recorded concentrations all less than the limit of detection. However, the limit of detection is greater than the screening value.

8.2 Receptors (Pre Development)

Principal receptors of contamination pre development are:-

- Human health - site users on this site and adjacent sites, the general public and workers involved with future development

- Site infrastructure – particularly buried services such as water mains and building foundations. Both can be affected by acid ground conditions, sulphates and hydrocarbons.

- Controlled waters -the site is underlain partly by a minor aquifer and partly by a major aquifer. The surface water and shallow groundwater are likely to drain into the River Medlock. Surface water and potentially groundwater may also drain into the Rochdale Canal, especially via land drains.

8.3 Receptors (Post Development)

Principal receptors of contamination post development are:-

- Human health - site users on this site and adjacent sites and maintenance workers involved with future maintenance of infrastructure and services.

- Site infrastructure – particularly buried services such as water mains and building foundations. Both can be affected by acid ground conditions, sulphates and hydrocarbons.

- Controlled waters -the site is underlain partly by a minor aquifer and partly by a major aquifer. The surface water and shallow groundwater are likely to drain into the River Medlock. Surface water and potentially groundwater may also drain into the Rochdale Canal, especially via land drains.

Surface water data for River Medlock and Rochdale canal, from the Ove Arups desk study report dated September 2002, indicates that the canal is designated as Canal Quality B (good), while the River Medlock is designated by the Environment Agency as River Quality E (poor).

8.4 Pathways

The potential pathways through which contamination could impact of the identified receptors are:-

- Human health exposure routes include direct contact, ingestion and inhalation.

- Migration of groundwater.

- Migration of liquids, vapours and gases through permeable strata, made ground and buried service culverts.

8.4.1 Pre development pathways

- Human health – Direct contact, ingestion and inhalation are the pathways which currently exist between the source and the human receptor. Site users and the general public walking across the site may come into direct contact, ingest or inhale contaminants.

- Migration of groundwater - MEL noted the presence of sand lenses within the glacial till and a number were identified during this investigation. If connected, these represent an available pathway for migration of contamination through the glacial till towards controlled waters. Free phase liquid hydrocarbons can migrate through the ground or via groundwater. Land drains present across the site and are known to contain free phase hydrocarbons. They present a particularly easy pathway for across site and off site migration of contaminants into surface waters and then to controlled waters.

- Migration of liquids and vapours – Permeable made ground and sand lenses within the glacial till can allow migration of liquids and vapours across and off site. Groundwater can migrate through pockets of contamination, leaching contaminants. Made ground across the site, including the backfilled ponds and reservoirs are producing methane and carbon dioxide, which can migrate through permeable strata or vent directly to the atmosphere presenting a risk to site users, and infrastructure of this site as well as adjacent areas. It is unlikely that site users will be affected by venting of ground gas due to dilution in the air.

8.4.2 Post development pathways

- Human health – If the site were to be covered with hard standing and occasional areas of landscaping utilising inert imported material, then the pathway between site users and sources of contamination is broken, removing the pollutant linkage.

- Migration of groundwater – Provision of impermeable hard standing across the site, and associated off site drainage will reduce the amount of surface water percolating through the contaminated ground. Removal of land drains, known to be contaminated with free phase hydrocarbons, will also reduce the ease with which contaminated groundwater can migrate across and off site. This will result in a reduction in the risk to groundwater. However, there is still a risk to controlled waters through residual contamination and ongoing migration of contamination towards and through the Sherwood Sandstone aquifer. A pollutant pathway still exists in this instance even with the development measures described above.

- Migration of liquids and vapours –As discussed above, provision of impermeable hard standing will still allow migration of liquids and vapours across and off site. Groundwater can still migrate through pockets of contamination, leaching contaminants. Made ground across the site, including the backfilled ponds and reservoirs are producing methane and carbon dioxide which can migrate across and off site through permeable strata. Provision of gas protection measures in any new buildings will remove the risk to site users and infrastructure on this site and adjacent sites by allowing the gas to vent safely to the atmosphere.

8.5 Pollutant Linkages

The following section takes the conceptual model initially developed in Section 4 of this report and refines it, taking into account the findings of this ground investigation. This is carried out to identify pollutant linkages associated with the site and to assess the requirements for remedial measures.

The risk is assessed using the three categories listed below:-

- High – Action must be taken to reduce the risk which is judged to be too high.

- Medium – There is sufficient evidence to suggest that there may be an unacceptable risk . Further work is needed before this can be rejected or accepted.

- Low – There is a low risk to the identified receptors, which should still be addressed with the aim of reducing the risk to a minimal acceptable level.

8.5.1 *Pre-Development*

Source	Pathway	Receptor	Risk
Contaminated made ground	Direct contact	Site users and infrastructure	Medium
	Migration of gas / vapours	Site users and infrastructure	High
	Ingestion	Site users	Medium
	Leaching of contaminants into the groundwater	Controlled waters and site infrastructure	High
Contaminated groundwater	Direct contact	Site users and infrastructure	Low
	Migration of gas / vapours	Site users and infrastructure	Medium
	Ingestion	Site users	Low
	Migration of contaminated fluids	Controlled waters and site infrastructure	High

Table 45. Summary of pollutant linkages for the site, pre development

8.5.2 *Post Development*

It has been assumed that the site will be covered with buildings and hard standing. This, together with associated drainage would form an impermeable barrier, preventing contact of the site users with the underlying materials. Removal of existing hydrocarbon contaminated land drains will reduce the available pathways for across and off site migration of contaminated shallow water.

Services should be placed in clean trench fill to prevent contaminants impacting on services, particularly water pipes. In areas where shallow ground water is present, the clean trench fill material should be impermeable.

Due to the large amount of uncapped area around the site, it is believed that ground gas is currently venting to the atmosphere. Development and provision of hard standing will alter the venting regime and may lead to increased lateral migration across and potentially off the site. It is therefore recommended that gas protection measures are incorporated within any new buildings.

Landscaped areas would require the provision of a suitable cover layer or the careful selection of suitable plants.

If these remedial measures are carried out, risks to the site user and infrastructure are therefore minimised to an acceptable level.

Source	Pathway	Receptor	Risk
Contaminated made ground	Leaching of contaminants into the groundwater	Controlled waters	Medium
Contaminated groundwater	Migration of contaminated fluids	Controlled waters	Medium

Table 46. Summary of pollutant linkages for the site, post remediation

Table 46 above indicates that provision of hard standing across the site and gas protection measures within new buildings removes most pollutant linkages to acceptable levels. Due to the presence of an impermeable barrier and associated off site drainage there is a reduction in the amount of surface water percolating through the contaminated ground. This will result in a reduction of the risk to controlled water.

However, there is still a risk to controlled waters through residual contamination and ongoing migration of contamination towards and through the Sherwood Sandstone aquifer and towards the River Medlock. Pollutant linkages still exist in this instance even with the development measures described above.

In order to fully assess the impact of the identified sources of contamination on controlled waters, a groundwater quantitative risk assessment has been carried out and is presented in the following section.

SECTION 9: GROUNDWATER QUANTITATIVE RISK ASSESSMENT

Following the screening exercise detailed in Section 7, a large number of Soil Guideline Value exceedences were identified. To fully assess the likely impact of these exceedences on controlled waters, a quantitative risk assessment was carried out on the site in its current un-remediated state and is detailed below. Copies of the key P20 spreadsheets showing all results, together with inputs, are presented together with summary tables in Appendix H.

9.1 Objectives

The objectives of the quantitative groundwater risk assessment are as follows:

- predict the potential concentrations of key contaminants at appropriate compliance points;
- set targets for key contaminants at the source, protective of water resources;
- provide a basis for a risk based remediation strategy for approval by the Environment Agency.

9.2 Methodology

The risk assessment uses the source→ pathway→ receptor (pollutant linkage) approach. This considers the movement of contaminants from a source to a specific receptor or compliance point via a pathway. The approach is summarised as follows:

- develop a conceptual site model which describes and characterises the key conditions and pollutant linkages at the site;
- determine appropriate screening values based on the most sensitive pollutant linkages identified in the conceptual model;
- undertake screening to identify contaminants of concern at the source;
- if warranted by the screening process, undertake further risk assessment to evaluate the potential for attenuation of contamination between the source and receptor:
- identify appropriate modelling package and level of model to be used to model the key pollutant linkages
- establish key input parameters based on the conceptual model
- undertake forward modelling to assess risks posed to receptors
- undertake reverse modelling to develop remediation target values (RTV) for the site – RTV's are the maximum contaminant concentrations at the source which do not pose an unacceptable risk to the receptor;
- feed results into the risk management strategy to alleviate risks posed by the site.

The approach used is based on guidance presented in Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources, Environment Agency R&D Publication 20, 1999 (P20).

For Tier 1 of the assessment a simple comparison has been made between screening values and site leachate and groundwater data. Any contaminant is identified as a CoC if any of the site results exceed the screening level. The identified CoC's are then considered further in Tier 3 soil and groundwater assessments. The Environment Agency P20 spreadsheets have been used for the Tier 3 assessment.

9.3 Data

Two phases of site investigation works have been undertaken by Parkman and the chemical data from these has been used in this assessment. An earlier investigation was undertaken by PB Kennedy and Donkin in 1999, this covered Areas 1 and 2. Only the PB Kennedy and Donkin chemical data from Area 2 and 3 was used in this assessment as Area 1 has been extensively reworked since the investigation was undertaken.

9.4 Conceptual Site Model

The ground conditions found during the site investigations are summarised as follows:

- made ground comprising ashy material;
- made ground comprising reworked glacial till;
- glacial till;
- sands and gravels at the base of the glacial till in hydraulic continuity with the underlying bedrock;
- Sherwood Sandstone/Westphalian C Coal Measures.

For the purposes of this risk assessment the two types of made ground have been considered as a single potential source of contamination. An initial review was undertaken on the variation of the contaminants across the site and strata. It was found that the contaminants were generally dispersed throughout the areas of the site with certain parts that were found to have particular elevated concentrations related to former site processes, such as the backfilled reservoir in Area 2. The contaminated areas are spread out through the whole of Areas 1-3.

Area 4 is separated from Areas 1-3 and has not been subject to the same processes, this site is considerably smaller.

According to the geological map that covers the site, the Sherwood Sandstone is shown to underlie Areas 1 and 4. Areas 2 and 3 are underlain by Westphalian C member of the Coal Measures. The Sherwood Sandstone is classified by the Environment Agency as a major aquifer, whilst the Westphalian is classified as a minor aquifer. The two units are separated by the Bradford Fault which trends northwest-southeast and dips at approximately 45° to the northeast. The Sherwood Sandstone is indicated to be the downthrown side. The block of sandstone is truncated to the east of the site by a second fault, again downthrown on the western side. This leaves the sandstone beneath the site forming a sliver that pinches out approximately 1.5km to the south of the site.

The results of the ground investigation indicate that the glacial till is present to a depth of between about 17-30m beneath the site. The glacial till is classified as a non-aquifer however slow groundwater movement is possible. It is anticipated that layering in this unit will result in reduced vertical permeability relative to horizontal and favour horizontal movement. The till includes thin sand and gravel layers which are unlikely to be laterally persistent. The glacial till may act as a pathway for migration of contamination laterally, whilst vertical migration is likely to be very limited.

The granular material present at the base of the till is likely to be in hydraulic continuity with the bedrock. This unit was detected in BH15 in Area 2 where it was approximately 10m in thickness. In BH 13 in Area 4 sand was detected at the base of the boulder clay, but may well represent the weathered surface of the Triassic Sandstone.

The direction of lateral groundwater flow within the glacial till based on a limited number of piezometers screened across the more granular layers has been determined to be towards the south east. Two plots showing the groundwater flow are presented in Appendix H. These are based on the groundwater monitoring undertaken by Soil Mechanics on 3rd April and 7th May 2003.

The River Medlock, the Rochdale Canal and the groundwater within the Sherwood Sandstone are possible receptors.

The level of the Rochdale Canal, which runs along the south eastern boundary of Area 4, was compared to the groundwater levels within Area 4. It was found that the water level in the canal was higher than the groundwater and as such it was decided that the canal was not at risk.

Since the glacial till is thick and will restrict vertical movement of groundwater the underlying Coal Measures and Sandstones are not considered significant potential receptors. This conclusion is supported by observations on contaminant concentrations. Groundwater from sands within the glacial tills (BH5 and BH4 in Area 2) had relatively low detected concentrations of contamination, whilst groundwaters from the deep boreholes incorporating sands at the base of the glacial till had higher levels of contamination. Furthermore the concentations of contamination associated with the bedrock were higher than those for the leachates generated from the made ground (eg TPH). In addition, the contaminants present in the deep made ground were different to those in the leachates. The highest concentrations of deep groundwater contamination were encountered in BH13 below thick clay, in what is suspected to be weathered Triassic Sandstone. If the shallow made ground was the major source of this deep contamination, significant attenuation and dilution would be anticipated as the groundwater migrated vertically through some 30m of clay rich till and entered the Triassic Sandstone, which would result in much lower concentrations of contamination in the deep groundwater.

Consequently the receptor to be used for the risk assessment was identified as the River Medlock. The River Medlock is situated approximately 350m south of Briscoe Lane that forms the south-eastern boundary of Areas 1-3. The River is approximately 850m from Area 4.

For the purposes of the risk assessment the four areas comprising the site were grouped into two zones, the first comprising Areas 1, 2 and 3, the second comprising Area 4. This was done as the conditions in areas 1, 2 and 3 were found to be similar, whilst area 4 is located separately to the north of areas 1-3.

The hydraulic conductivity for the glacial till was taken from an adjacent site where a groundwater risk assessment was undertaken. The till was thought to be sufficiently similar to justify the use of the same conductivity.

9.5 Screening Values

As surface water was identified as the receptor at risk the Environmental Quality Standards (EQS's) were used for the screening, where available. Where an EQS was not available the appropriate UK Drinking Water Standards (UK DWS) were used instead. The leachate results were then screened against these standards. Table 46 below lists the screening values used and their sources.

For PAH's the screening value used for the modelling of the individual PAH's was 1/16th of the UK drinking water standard for total PAH. Likewise, for TPH, the screening value used for the modelling was 1/13th of the UK drinking water standard as TPH was modelled as the 13 fractions of the TPH CWG method. In each case this approach is conservative and higher standards could reasonably be used with more information and analysis.

Contaminant	Screening Value mg/l	Source
Arsenic	0.05	EQS
Boron	2	EQS
Cyanide (Total)	0.05	UK DW
Mercury	0.001	EQS
Selenium	0.01	EQS
Phenol	0.0005	UK DW
Cadmium	0.005	EQS
Chromium	0.05	EQS
Copper	3	UKDW
Nickel	0.05	EQS
Lead	0.05	EQS
Zinc	5	EQS
pH	9.5	EQS
Cyanide (Free)	0.05	UK DW
Total Sulphur as SO_4	250	EQS
TPH	0.01	UK DW
PAH	0.0002	UK DW

Table 47 - Screening values used for the QRA.

9.6 Tier 1 Assessment: Contaminants of Concern

When the leachate results were compared to the screening values identified in the previous section the following CoC's were identified:

9.6.1 Area 4

- TPH
- Naphthalene
- Acenaphthylene
- Acenaphthene
- Fluorene
- Phenanthrene
- Anthracene
- Fluoranthene
- Pyrene

9.6.2 Areas 1-3

- TPH
- Naphthalene
- Acenaphthylene
- Acenaphthene
- Fluorene
- Phenanthrene
- Anthracene
- Fluoranthene
- Pyrene
- Benz(a)anthracene
- Chrysene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Dibenzo(ah)anthracene
- Benzo(ghi)perylene
- Indeno(123cd)pyrene

For the PAH's in both areas, where the total PAH was found to be above the screening value the individual PAH's that were above the detection limit were idenitified as CoC's.

All samples tested for mercury were found to be below the detection limit of the analytical method used. Due to problems with the analysis the detection limit was varied for some samples, in these cases the detection limit was higher than the screening value. However since all those samples with a limit of detection below the EQS had results below detection limit and mercury was not detected in any sample, it was concluded that there was no significant risk from mercury.

9.7 Soil and Groundwater Risk Assessment

9.7.1 Compliance Point

For the risk assessment the River Medlock was identified as the receptor at risk. For Areas 1-3 the distance to the Medlock was set as 343m. For Area 4 the distance to the Medlock was set at 850m. These distances are the shortest distance to the river from the appropriate areas and not the distance in the direction of groundwater flow. This provides a more conservative assessment of the migration of CoC's to the receptor.

9.7.2 Model Input Data

The model input data are presented with the source or justification for the input in Appendix H.

For the modelling no dilution in the River Medlock was allowed.

When calculating the infiltration for the site a water balance was undertaken to ensure that the infiltration did not greatly affect the hydraulic gradient. Due to the size of the groundwater catchment upgradient of the site, compared to the site area it was concluded that groundwater flow below the site would be large compared to infiltration through the site. An infiltration rate was therefore selected to reflect this, but also which was consistent with the low hydraulic conductivity of the materials present.

For modelling TPH was divided into the thirteen fractions of the TPH Criteria Working Group. As the analysis for TPH had been done as a mixture of total TPH, PRO, GRO and DRO the concentrations used for a fraction were a mixture of the available analyses. This meant the concentrations used for each of the fractions were probably an overestimate of the concentrations actually present.

9.7.3 Results

Copies of the key P20 spreadsheets showing all results, together with inputs, are presented together with summary tables in Appendix H. The RTV's are presented together with the highest measured values on site in Tables 47 and 48 below.

In Areas 1-3 none of the CoC's were found to exceed the Tier 3 remedial targets for soil or groundwater with the exception of the following:

- the aliphatic fraction >C16-C21;
- the aromatic fractions >C16-C21 and >C21-C35;

for which Tier 3 soil and groundwater RTV's were exceeded.

For Area 4 none of the CoC's were found to exceed the Tier 3 remedial targets for soil or groundwater.

Contaminant	Soil (mg/kg)		Leachate (mg/l)		Water (mg/l)	
	RTV	Max Conc	RTV	Max Conc	RTV	Max Conc
Naphthalene	1.16E+13	209.575	2.28E+08	0.002204	2.25E+25	0.0127
Acenaphthylene	8.67E+23	14.595	4.56E+19	0.001856	2.46E+47	0.0167
Acenaphthene	1.88E+22	107.469	1.01E+18	0.008452	1.62E+44	0.0376
Fluorene	4.65E+25	132.719	2.50E+21	0.00516	5.33E+50	0.0202
Phenanthrene	8.04E+15	684.221	1.16E+10	0.000362	5.54E+28	0.0405
Anthracene	1.82E+08	232.465	1.45E+03	0.002015	5.56E+14	0.015
Fluoranthene	6.64E+07	625.982	2.55E+02	0.002821	1.41E+13	0.0964
Pyrene	1.04E+03	564.782	4.48E-03	0.002252	2.08E+02	0.0879
Benz(a)anthracene	6.21E+06	302.13	7.64E+00	0.000308	7.17E+09	0.0234
Chrysene	3.80E+04	208.445	5.80E-02	0.000285	1.08E+05	0.012
Benzo(b)fluoranthene	1.28E+06	276.887	9.24E-01	0.000212	5.18E+12	0.00623
Benzo(k)fluoranthene	8.50E+02	76.854	9.42E-04	0.000077	3.66E+00	0.00564
Benzo(a)pyrene	2.96E+08	179.779	2.17E+02	0.000136	1.01E+13	0.0119
Dibenzo(ah)anthracene	1.73E+05	139.289	8.43E-02	0.00006	2.61E+05	0.00658
Benzo(ghi)perylene	1.37E+05	29.912	1.20E-01	0.000021	6.02E+05	0.00556
Indeno(123cd)pyrene	5.71E+04	70.714	7.19E-02	0.000092	1.79E+05	0.00144
Aliphatic Fractions						
>5-6	9.62E+04	3.384	9.90E+02	0.334	2.26E+12	59.3
>6-8	9.77E+04	3.384	9.90E+02	0.334	2.26E+12	59.3
>8-10	1.18E+04	6072.01	5.91E-01	0.373	8.60E+04	59.3
>10-12	1.18E+04	6072.01	5.91E-01	0.373	8.60E+04	59.3
>12-16	1.19E+04	6072.01	5.91E-01	0.373	8.60E+04	59.3
>16-21	8.51E+02	6072	3.08E-02	0.28	4.06E+01	59.3
Aromatic Fractions						
>5-7 (benzene)	9.34E+04	3.384	9.90E+02	0.334	2.26E+12	59.3
>7-8 (toluene)	9.34E+04	3.384	9.90E+02	0.334	2.26E+12	59.3
>8-10	1.18E+04	6072.01	5.91E-01	0.373	8.60E+04	59.3
>10-12	1.18E+04	6072.01	5.91E-01	0.373	8.60E+04	59.3
>12-16	1.18E+04	6072.01	5.91E-01	0.373	8.60E+04	59.3
>16-21	8.37E+02	6072	3.08E-02	0.28	4.06E+01	59.3
>21-35	8.37E+02	6072	3.08E-02	0.28	4.06E+01	59.3

Table 48 - Summary of RTV's and maximum concentrations for Areas 1-3

It should be noted that some very high RTV values have been calculated by the P20 model. These are not intended to represent real concentrations that could occur, but indicate that the contaminant could not represent a significant risk at any concentration.

Contaminant	Soil (mg/kg)		Leachate (mg/l)		Water (mg/l)	
	RTV	Max Conc	RTV	Max Conc	RTV	Max Conc
Naphthalene	5.74E+44	209.575	7.69E+40	0.0333	4.29E+60	9.83
Acenaphthylene	8.81E+76	14.595	1.03E+75	0.123	5.77E+106	0.615
Acenaphthene	2.30E+72	107.469	1.20E+70	0.618	1.30E+100	1.05
Fluorene	2.36E+83	132.719	1.54E+80	0.0402	5.33E+113	0.42
Phenanthrene	1.67E+51	684.221	1.34E+46	0.00082	5.59E+67	0.364
Anthracene	3.39E+28	232.465	3.55E+24	0.00197	1.95E+38	0.056
Fluoranthene	5.67E+25	625.982	1.27E+22	0.0229	8.18E+34	0.144
Pyrene	2.95E+09	564.782	4.79E+05	0.0111	4.62E+11	0.462
Aliphatic Fractions						
>5-6	1.06E+23	1400.24	8.72E+19	3.04	1.62E+31	41.8
>6-8	1.07E+23	1400.24	8.72E+19	3.04	1.62E+31	41.8
>8-10	6.20E+11	1400.24	5.07E+08	3.04	1.82E+15	41.8
>10-12	6.22E+11	1400.24	5.07E+08	3.04	1.82E+15	41.8
>12-16	6.40E+11	1400.24	5.07E+08	3.04	1.82E+15	41.8
>16-21	9.67E+06	1400.24	5.86E+03	3.04	8.32E+07	41.8
Aromatic Fractions						
>5-7 (benzene)	1.06E+23	1400.24	8.72E+19	3.04	1.62E+31	41.8
>7-8 (toluene)	1.06E+23	1400.24	8.72E+19	3.04	1.62E+31	41.8
>8-10	6.17E+11	1400.24	5.07E+08	3.04	1.82E+15	41.8
>10-12	6.17E+11	1400.24	5.07E+08	3.04	1.82E+15	41.8
>12-16	6.17E+11	1400.24	5.07E+08	3.04	1.82E+15	41.8
>16-21	7.13E+06	1400.24	5.86E+03	3.04	8.32E+07	41.8
>21-35	7.13E+06	1400.24	5.86E+03	3.04	8.32E+07	41.8

Table 49 - Summary of RTV's and maximum concentrations for Area 4

9.8 Sensitivity Analysis

Following the initial modelling with the compliance point set to the River Medlock sensitivity analysis was undertaken in order to determine the contaminants that would exceed the remedial target for a closer compliance point and also to enable a estimation of the travel time for the contaminants to reach this new compliance point. This gives an idea as to whether the contaminants would actually reach a receptor in a realistic timescale.

The sensitivity analysis was accomplished by first re-running the model with a compliance point of 100m for the contaminants in Areas 1-3. Then, for the contaminants that were found to exceed the remedial targets for soil, leachate or groundwater, the approximate time it would take for the contaminants to first reach the 100m compliance point was calculated.

Given the greater distance to the original compliance point and the lower concentrations of contaminants in Area 4 combined with the lack of exceedences in this area no further modelling was undertaken for Area 4.

The results of this modelling found that the following contaminants exceed the tier 3 soil and/or leachate remedial targets in Areas 1-3:

- Pyrene
- Chrysene
- Benzo(k)fluoranthene
- all Aliphatic TPH fractions
- all Aromatic TPH fractions.

The following contaminants were found to exceed the Tier 3 water remedial target:

- Pyrene
- Chrysene
- TPH Aliphatic fraction >C16-C21.

The travel time estimation was undertaken by using the Time Variant Domenico solution and then adjusting the time since the pollutant entered the groundwater until it first reaches the compliance point.

The times taken for those contaminants listed above to first reach the compliance point are presented in the following table.

Contaminant	Time taken to reach 100 m compliance point (years)	
	Tier 3 Soil	Tier 3 Water
Pyrene	$5x10^4$	$2x10^5$
Chrysene	$2x10^5$	-
Benzo(k)fluoranthene	$1x10^6$	$2x10^6$
TPH Aliphatic Fractions		
>C5-C6	$1x10^3$	-
>C6-C8	$1x10^4$	-
>C8-C10	$2x10^4$	-
>C10-C12	$2x10^5$	-
>C12-C16	$3x10^6$	-
>C16-C21	$3x10^8$	$1x10^9$
TPH Aromatic Fractions		
>C5-C7	$5x10^1$	-
>C7-C8	$2x10^2$	-
>C8-C10	$8x10^2$	-
>C10-C12	$2x10^3$	-
>C12-C16	$3x10^3$	-
>C16-C21	$3x10^8$	$1x10^9$
>C21-C35	$3x10^8$	$1x10^9$

Table 50. Summary of time taken for contaminants to reach the compliance point.

Where no value is shown for the Tier 3 water the contaminant does not reach the compliance point.

From the above table it can be seen that all of the contaminants take in excess of 1,000 years to reach the compliance point with the exception of the following Aromatic TPH fractions in soils:

- >C5-C7, >C7-C8 and >C8-C10.

For these fractions the travel time was found to be between 50 and 800 years. For the Tier 3 water contaminants the travel time was found to be in excess of 200,000 years for all contaminants.

It should noted however that for all of the TPH fractions due to the lack of fractionated TPH results the total TPH results were used. For all of the modelling the option for biodegradation only occurring in water was selected, this leads to very conservative remedial targets being produced. One of the assumptions of the P20 model is that there is a non-depleting source, given the extremely long times for the contaminants to reach the 100m compliance point there will in reality be a considerable degradation in the concentrations of the contaminants at the source.

9.9 Conclusions

The exceedences of the calculated Tier 3 TPH remedial targets are probably a reflection of the fact that the TPH analysis was not done to the TPH CWG (TPH Criteria Working Group) method and the concentrations used in the calculations represented a number of fractions i.e. an over-estimate of the amount of a particular fraction present. Since the exceedences of the Tier 3 RTV's are moderate, the presence of exceedences of the remedial targets will probably be resolved by further sampling and analysis to the CWG method and remodelling of the TPH fractions. Further sampling and analysis from Areas 1-3 should indicate that there is not a risk to the groundwater from the TPH on the site.

For Area 4 no remedial action is required as there is not a significant risk posed to water resources.

At this stage it is not considered that the site presents a risk to controlled waters.

SECTION 10: REMEDIAL MEASURES

10.1 Summary of Identified Risks

10.1.1 Pre Development

A detailed study of the significant pollutant linkages is presented in Section 8.5 and further developed in Section 9. Following the groundwater QRA the remaining potential pollutant linkages are associated with human health and infrastructure. It is assumed that the grossly contaminated drains and service duct will be removed.

Source	Pathway	Receptor	Risk
Contaminated made ground	Direct contact	Site users and infrastructure	Medium
	Migration of gas / vapours	Site users and infrastructure	High
	Ingestion	Site users	Medium
	Leaching of contaminants into the groundwater	Controlled waters and site infrastructure	High
Contaminated groundwater	Direct contact	Site users and infrastructure	Low
	Migration of gas / vapours	Site users and infrastructure	Medium
	Ingestion	Site users	Low
	Migration of contaminated fluids	Controlled waters and site infrastructure	Low

Table 51. Summary of pollutant linkages for the site following the groundwater QRA.

10.1.2 Post Development

Assuming that the site is redeveloped for industrial/commercial end-use with buildings and hard standing, no residual pollutant linkages are considered to exist.

10.2 Identification of Remedial Measures

The remedial assessment outlined below has been undertaken using professional judgement, without reference to the appropriate Regulatory bodies. There is some risk that the regulators may not agree with the assumptions made and therefore require further testing/remedial works to be undertaken.

One way to remove the pollutant linkages is to "break" the pathway between the site end-users and the source of the contamination. In the long term it is assumed that the site will be redeveloped for industrial/commercial end-use. In the short to medium term, prior to redevelopment, in order to remove statutory liabilities it is recommended that the site is "capped". Both options are discussed below.

10.2.1 Option 1 – Provision of hard standing across the site.

Option 1 assumes a hard standing cover layer could be utilised across the whole site. Preliminary costings for construction of this cover layer are included below. Two options have been provisionally costed:- provision of a medium term solution comprising 250mm depth of granular material across the site or provision of a permanent tarmacadam cover with drainage across the site.

No CBR test results are available for the made ground across the site. For provision of hard standing, an average CBR (Californian Bearing Ratio) of 2% has been utilised.

It is also assumed that the existing off-site surface water drainage system can cope with any possible increase in surface water run-off associated with this development. However if construction were to occur, qualified drainage engineers should carry out a detailed study of the suitability of the existing sewer infrastructure.

For costing purposes, it is assumed that site levels can be raised. If this is not the case, and material is required to be removed to prevent elevation of site levels, this will require off site disposal if a use for it cannot be found on site.

Vehicle use across the hard standing would be limited. Heavy goods vehicles would be restricted to the roadways provided and therefore the minimum allowable frost resistant hard standing pavement construction has been utilised.

The short to medium term solution would consist of:

- 250mm depth of compacted 6F2 or Type 1 granular material

The permanent tarmac cover would consist of:

- 450mm depth of compacted 6F2 or Type 1 granular material. This is the minimum to be frost resistant.
- 100mm depth of sub-base
- 60mm depth of base course
- 40mm depth of wearing course

10.2.2 Option 2 – Industrial Development with Business units and landscaping areas.

Option 2 assumes industrial development comprising business units, hard standing and a limited proportion of landscaped areas. The phytotoxic screening indicates that the soils currently present on site are unsuitable for sustaining most plant life. A suitable planting medium should be provided in landscaping areas. This will also provide a suitable barrier between site users and underlying contamination. Alternatively phytotoxic plants could be selected. For costing purposes, it is assumed that site levels can be raised. If this is not the case, and material is required to be removed to prevent elevation of site levels, this will require off site disposal if a use for it cannot be found on site.

10.2.3 Outstanding Environmental Issues

Particular environmental areas still requiring consideration are:

- Additional testing may be required by The Environment Agency to further speciated the groundwater TPH results in Areas 1-3 to confirm the organics present represent a spread of compounds not just the most toxic.

- There is a concern that there may be higher levels of PCB contamination in the area of TP12 and TP13 that were not detected during the site investigation. If this area of the site was to be covered by buildings or hard standing it is unlikely that any remediation would be required. However in order to give further confidence we would recommend that during demolition an appropriately trained and experienced environmental scientist is present to visually assess the material. If necessary take further samples would be taken to confirm that there are no areas where PCBs are present in greater concentrations than have already been detected. At this stage we would suggest that an allowance is made for the removal of $500m^3$ of PCB contaminated material.

- The contaminant levels associated with the "tarry" material within the lagoons would be likely to preclude its re-use on-site.

- Given the very mixed nature of the made ground it is recommended that a provisional item of $500m^3$ of material requiring removal is included in any cost estimate. This would cover removal of previously unidentified unacceptable material during redevelopment.

- Japanese Knotweed (JKW) has been identified in two areas; the northeast corner of Area 1 and along the boundary between Area 4 and Bower Street. The three stands in the north east corner of Area 1 (at late May 2003) cover an area of some $36m^2$. In accordance with best practice, material should be removed from up to 7m away from the original stand and down to a depth of 3m. This equates to a volume of $3770m^3$. Excavation and disposal has been chosen as the current treatment method as English Partnerships have indicated that this area would be developed early on within any programme. If this area could be chemically treated over a period of 3-5 years significant cost savings may be achieved. English Partnerships have not currently identified Area 4 as a priority development area. A chemical treatment solution (bearing in mind the vicinity of the canal) will therefore be the most appropriate solution for this area. Allowing the spread of this plant is an offence under the Wildlife and Countryside Act 1981. Remediation of this plant can be both expensive and time consuming and the longer the plant is left before being treated, the larger the area that will require treatment as this plant spreads very rapidly and hence costs will increase proportionally. Chemical treatment of Japanese Knotweed is ideally carried out using two visits per year, ideally during the growing season.

The cost at current values is likely to be in the order of £300 excluding VAT per visit. Herbicidal treatment would need to be undertaken during the growing season, from April to September, probably for a period of 3-5 years. If the areas containing Japanese Knotweed could be left undisturbed for this period, then herbicidal treatment is the most cost effective.

The assessments made in this report have been undertaken without reference to the appropriate Regulatory bodies, using our professional judgement. There is some risk that the regulators may not agree with the assumptions made and therefore require further testing/remedial works to be undertaken.

The groundwater risk assessment considered Areas 1,2 and 3 as one site and Area 4 as a separate area. It is possible that if the site was redeveloped, Areas 1-3 may fall into separate ownership, which would mean that each area may need to be considered separately. This could result in further remediation being required than has been currently identified. Each area has been considered separately with regards to human health.

If material is excavated and then re-used on-site it would be necessary to undertake the works in accordance with the Waste Management Licensing Regulations - it is possible that such works would be covered by an Exemption. Confirmation of this is required from the Environment Agency. For the purposes of these estimates it has been assumed that such an Exemption would be granted. If this was not the case and the works required a Waste Management Licence any future development may be considered "blighted". The granting of such exemptions is becoming evermore difficult to judge and there is a risk that an Exemption would not be granted in which case any excavated material would have to be disposed of off-site.

It is considered likely that much of the material could be disposed of off-site under an Exemption from Landfill Tax as the site is historically contaminated. If this was not the case, disposal rates would be increased by £14/t (based on current rates).

Disposing of contaminated soils to landfill is going to become increasingly expensive with the full implementation of the Landfill Directive. This will have the effect of increasing costs for remediation projects that involve landfill disposal. The greater the delay in undertaking these works the greater the risk that the indicative rates provided will be an underestimate of the costs.

The basis for the remedial costs is a technical risk assessment. Issues such as funders and public perception may have a significant impact on any remedial solutions. Such issues are outside the scope of this report.

10.3 Cost Estimates for Remediation of Environmental Issues

The following table presents the cost estimate ranges for the various treatment solutions.

	Area 1	Area 2	Area 3	Area 4	Volume (m^3)	% age off site	Rate * (£ / m^3)	Hard Standing Option		Redevelopment Option	
								Low Cost (£)	High Cost (£)	Low Cost (£)	High Cost (£)
Removal of PCB contaminated material	500 m^3				500	100	70	35,000	35,000	35,000	35,000
Contingency for removal of hotspots	500 m^3				500	100	70	35,000	35,000	35,000	35,000
Additional testing to meet EA/EHO requirements	£3,000				N/A	N/A	N/A	3,000	3,000	3,000	3,000
Removal of land drains and reservoir service drains	£40,000				N/A	N/A	N/A	40,000	40,000	40,000	40,000
Chemical Treatment of Japanese Knotweed	£3,000				N/A	N/A	N/A	3,000		3,000	
Excavation and disposal of Japanese Knotweed	3770 m^3			675 m^3	4445	100	70		311,150		311,150
Provision of granular hard standing across the site	£608,000	£277,000	£183,000	£106,000	N/A	N/A	N/A	1,174,000			
Provision of tarmac hard standing across the site	£1,775,000	£810,000	£535,000	£310,000	N/A	N/A	N/A		3,430,000		
							TOTAL (£)	**1,290,000**	**3,854,150**	**116,000**	**424,150**

Table 52. Summary of cost estimates for environmental issues

Rate assumes that exemption from landfill tax has been granted.

10.4 Summary of Development Abnormals

In addition to addressing the environmental issues at the site, further costs will be incurred as part of any redevelopment due to the specific ground conditions at the site. At the request of English Partnerships, various options were considered.

Both options include estimated costs for;

- Removal of the former service duct and removal of foundations.
- Piled foundations
- Gas protection measures
- Provision of clean trench fill for services
- Landscaping
- Re-working of the retaining wall along the southern boundary of Areas 1 and 2
- If dewatering is required as part of redevelopment, treatment of shallow groundwater within Area 4 prior to discharge to foul sewer will be required.

- It should be noted that the range of costs does not include normal development costs such as hard standing or car parking.

The results for the phytotoxic contaminants indicate that the soil is not suitable for general planting. Imported soil would be required in landscaping areas. For each area, two options for landscaping are provided. Each assumes that 15% of a typical commercial/industrial site would be landscaping, that site levels cannot significantly increase and that any excavated material can be re-used on site. It is assumed that that an Exemption from Waste Management Licensing Regulations would be granted to enable its re-use on-site. The granting of such Exemptions is becoming evermore difficult to judge and there is a risk that an Exemption would not be granted in which case the material would have to be disposed of off-site. Option 1 assumes that a 150mm cover of topsoil is provided, together with phytotoxic resistant plants. Option 2 assumes a 350mm subsoil layer and 150mm topsoil layer with standard plants. The costs assume a rate of £70 per m^3 for import of soil.

10.4.1 Area 1

- Buried Structures

Buried structures were encountered within Area 1 in approximately 25% of trial pits. These generally consisted of floor slabs, concrete pad foundations and machine beds. In the southern part of Area 1, a number of large (approximately $30m^2$) concrete slabs, (probably former machine beds) were identified together with a number of concrete pads located in the approximate position of the south west corner of the former machine shed. The floor slab of the former machine shed is still present with identified and probably some unidentified basements along the southern and eastern boundaries of the site. It is understood from Weir Pumps that their demolition contractors were only required to remove the former machine shed to ground level. It is believed that they were not required to remove any foundations. Weir Pumps have, as discussed above allowed some re-grading work to occur across Area 1 and this work may have buried former foundations which would otherwise have been visible. A nominal contingency of £80,000 has been allowed for Area 1, for removal of the former service duct encountered in TP16 and for the removal of former foundations, some of which may only be found during re-development excavations.

- Foundations

It is assumed that the site would be developed with 10,000-20,000ft^2 sheds of single storey portal frame construction. Foundation design, particularly slab design, will be dependent on the actual design requirements, particularly allowable differential settlements and loadings.

For much of Area 1 shallow foundations; pads and strips would generally be suitable to support the frame. The west side of Area 1 includes an area of deeper made ground and piles may be required to support the frame in this area. A sum of £100,000 has been allowed for this item. It is assumed that a ground bearing slab would be suitable. Sensitive end uses where maintenance of a very uniform floor level is required have been excluded. It has been assumed that piles would not be required below the slab; this would increase the costs of any development significantly.

- Soil Gas

Soil gas monitoring to date has indicated that Area 1 falls under Characteristic Situation 2 and therefore would include passive venting under building footprints. A sum of £20,000 has been allowed for this item.

- Services

Services would need to be placed in clean material and therefore material may also require off-site disposal.

Estimated run length of service trenches = 600m

Cross sectional area of trench = 1.2 x 1.0 = 1.2m^2

Volume = 720m^3

It is assumed that 50% of the material from services trenches could be re-used on-site. The remainder would require off-site disposal and it is possible that a landfill tax exemption may not be granted for such arisings. A sum of £35,280 has been allowed for this item, based on a rate of £98 per m^3.

- Landscaping

Using the above assumptions for landscaping, and taking Area 1 as covering 6.22 ha;

Option 1: 1,400m^3 of topsoil is required for import (£98,000)

Option 2: 4,668m^3 of soil (30% subsoil and 70% topsoil) is required for import (£326,760)

- Reworking of the boundary with Briscoe Lane

The southern boundary with Briscoe Lane is formed by what is believed to be a brick built retaining wall including basements accessed from the level of Briscoe Lane. This retaining wall is of unknown condition and therefore it is recommended that the wall be removed and the boundary be battered back to a 45° angle for stability. A sum of £100,000 has been allowed for this item.

10.4.2 Area 2

Due to the nature of the "tarry/oily" material in the former clay pit and reservoir careful consideration will need to be given to development options for these areas. Piling could create further migration pathways for waterborne contamination.

- Foundations

The ground conditions across Area 2 are generally poorer than Area 1, with low SPT 'N' values in the made ground and upper natural deposits. As with Area 1 it has been assumed that any slabs can be ground bearing (this would depend on loading and settlement criteria) but the frames would be supported on piles. A sum of £200,000 has been allowed for this item. Consideration would need to be given to pile selection to minimise the risk of creation of further pathways.

- Soil gas

Monitoring of BH7 has consistently encountered significantly elevated concentrations of carbon dioxide, but no methane, consistent with Characteristic Situation 4 as defined by CIRIA 149. Other boreholes indicated gas readings consistent with Characteristic Situation 2. Characteristic Situation 4 requires the use of an in-ground barrier below any developments. It is assumed that this would apply to approximately half of the site, based on the positions of the existing boreholes. A sum of £50,000 has been allowed for this item.

- Services

Services would need to be placed in clean material and therefore material may also require off-site disposal.

Estimated length of service trenches = 500m

Volume = 500 x 1.2 = 600 m^3

It is assumed that 50% of the material from services trenches could be re-used on-site. The remainder would require off-site disposal and it is possible that a landfill tax exemption may not be granted for such arisings. A sum of £58,800 has been allowed for this item, based on a rate of £98 per m^3.

- Landscaping

Based on the same assumptions as Area 1, i.e. any excavated material can remain on-site and taking Area 2 as covering 2.83 ha;

Option 1: 637m^3 of topsoil is required for import (£45,590)

Option 2: 2,124m^3 of soil (30% subsoil and 70% topsoil) is required for import (£148,680)

- Reworking of the south western boundary

The boundary with Briscoe Lane and Grimshaw Lane in the south western corner is formed by what is believed to be a brick built retaining wall including basements accessed from the road level. This retaining wall is of unknown condition and therefore it is recommended that the wall be removed and the boundary be battered back to a 45° angle for stability. A sum of £50,000 has been allowed for this item.

10.4.3 Area 3

- Foundations

Based on the existing data it would appear likely that pad and strip foundations would be suitable. This, as in all cases, is dependent on the required load and settlement criteria.

- Soil Gas

Monitoring results to date correspond to Characteristic Situation 1. No measures are required.

- Services

Services would need to be placed in clean material and therefore material may also require off-site disposal. Based on the same assumptions as Area 1, ie 50% of the material can remain on-site.

Estimated length of service runs = 500m

Volume = 500 x 1.2 = 600 m^3

It is assumed that 50% of the material from services trenches could be re-used on-site. The remainder would require off-site disposal and it is possible that a landfill tax exemption may not be granted for such arisings. A sum of £58,800 has been allowed for this item, based on a rate of £98 per m^3.

- Landscaping

Based on the same assumptions as Area 1, i.e. any excavated material can remain on-site and taking Area 3 as covering 1.87 ha;

Option 1: 420m^3 of topsoil is required for import (£29,400)

Option 2: 1,402m^3 of soil (30% subsoil and 70% topsoil) is required for import (£98,140)

10.4.4 Area 4

- Buried Structures

Buried structures were encountered within Area 4 in approximately 10% of trial pits. These generally consisted of brick wall foundations. These were quite minor in nature and would not be associated with any major costs.

- Foundations

Based on the assumption that slabs can be ground bearing, and given the depth of made ground and shallow depth of groundwater, then it is recommended that the proposed portal framed sheds are piled. A sum of £100,000 has been allowed for this item.

- Soil Gas

Monitoring results to date correspond to Characteristic Situation 2. A sum of £10,000 has been allowed for this item.

- Services

Services would need to be placed in clean material and therefore material may also require off-site disposal. Based on the same assumptions as Area 1, ie 50% of the material can remain on-site.

Estimated length of service runs = 500m

Volume = 500 x 1.2 = 600 m3

It is assumed that 50% of the material from services trenches could be re-used on-site. The remainder would require off-site disposal and it is possible that a landfill tax exemption may not be granted for such arisings. A sum of £35,280 has been allowed for this item, based on a rate of £98 per m^3.

- Landscaping

Based on the same assumptions as Area 1, i.e. any excavated material can remain on-site and taking Area 4 as covering 1.08 ha;

Option 1: 243m^3 of topsoil is required for import (£17,010)

Option 2: 810m^3 of soil (30% subsoil and 70% topsoil) is required for import (£56,700)

- Treatment of shallow groundwater in excavations

Shallow groundwater at approximately 1m bgl was encountered in the north east corner of the site adjacent to the canal. The water appeared visually contaminated and if dewatering is required as part of redevelopment, treatment prior to discharge to foul sewer will be required. It is estimated that the likely costs of this treatment would be in the order of £20,000, but a more accurate figure should be sought from specialist contractors. The rate would depend upon the length of time the excavation requires dewatering, flow rates and the precise nature of the contaminant.

10.5 Cost Estimates for Development Abnormals

	Area 1 (£)	Area 2 (£)	Area 3 (£)	Area 4 (£)	Low Cost (£)	High Cost (£)
Removal of buried structures	80,000				80,000	80,000
Foundations	100,000	200,000		100,000	400,000	400,000
Soil Gas	20,000	50,000		10,000	80,000	80,000
Clean trench fill**	35,280	29,400	29,400	17,640	111,720	111,720
Landscaping * Import of 150mm depth of topsoil	98,000	45,590	29,400	17,010	190,000	
Landscaping * Import of 350mm depth of subsoil and 150mm depth of topsoil	326,760	148,680	98,140	56,700		630,280
Removal of retaining walls	100,000	50,000			150,000	150,000
Dewatering of Excavations				20,000	20,000	20,000
				TOTAL	1,031,720	1,472,000

Table 53. Summary of cost estimates for development abnornals

* Assumes a rate of £70 per m^3 and that an exemption from landfill tax has been granted.

** Assumes a rate of £98 per m^3 and that an exemption from landfill tax has been granted.

SECTION 11: CONCLUSIONS AND RECOMMENDATIONS

The remediation strategy proposed essentially consists of two options.

- Provision of hard standing across the site. This has been split to provide two options; either provision of a medium term solution consisting of 250mm depth of inert granular fill material or provision of a permanent tarmac cover.
- Industrial redevelopment with business units and landscaping areas.

In addition, both the above options will need to include:

- Remediation of the two identified stands of Japanese Knotweed should be addressed through either excavation and disposal or by chemical treatment.
- Removal of contaminated land drains in Area 1 and contaminated service drains associated with the former reservoir in Area 2.

A number of environmental contingency items should be allowed for:

- Additional testing may be required by The Environment Agency to further speciated the groundwater TPH results.
- An appropriately trained and experienced environmental scientist should ideally be present on site during re-development of the area where PCBs were detected to visually assess the material. A provisional item of $500m^3$ of material requiring removal should be included in the cost estimate to cover the removal of PCB contaminated material.
- A provisional item of $500m^3$ of material requiring removal should be included in the cost estimate to cover the removal of previously un-identified unacceptable material during re-development.

The estimated costs for remediation based on a simple cover solution are likely to range from **£1.3M to £3.9M**.

The estimated costs for remediation if the site were redevelopment is likely to range from **£116K to £425K**. The costs for redevelopment do not include for normal development costs such as provision of buildings, hard standing or car parking.

The scope and outline of any remediation scheme designed will have to be agreed with the Environmental Health Officer from Manchester City Council, as well as the Environment Agency.

In addition to the environmental liabilities present at the site, a number of development abnormals have been identified. Cost estimates have been prepared for the development abnormals which essentially consist of:

- Removal of the former service duct and removal of foundations
- Piled foundations
- Gas protection measures in buildings
- Provision of clean trench fill for services

- Landscaping
- Battering back of the southern boundary of Area 1 and south western corner of Area 2
- If dewatering is required as part of redevelopment within Area 4, then treatment will be required prior to discharge to foul sewer.

The cost estimate for abnormals is between **£1.03M and £1.5M**. These costs do not include for normal development costs such as hard standing or car parking.

If the site were to be redeveloped, the levels of soil gas would need to be assessed over a longer period to identify the requirements for venting measures with the new buildings.

Six monitoring visits have been undertaken to date. Assessing the results against CIRIA Report 149 "Protecting Development from Methane" indicates the following:-

Area 1, part of Area 2 and Area 4 of the site are classified by CIRIA 149 as characteristic situation 2. In addition, part of Area 2 is classified as characteristic situation 4, and Area 3 is classified as characteristic situation 1.

It should be highlighted that numerous remnant structures were noted during the fieldwork that would probably require removal prior to redevelopment.

Any development works carried out on the site should take into account the Health and Safety of any construction workers, and appropriate Health and Safety practices and Personal Protective Equipment (PPE) should be worn when potentially contaminated materials.

A Planning Supervisor and a Principal Contractor will need to be appointed for any remediation or development works in accordance with the Construction Design and Management (CDM) Regulations, 1994.

SECTION 12: REFERENCES

MEL Ltd, September 1995. Environmental Audit, Mather and Platt Works, Newton Heath, Manchester. Prepared for Weir Pumps Ltd.

Mather and Platt, February 1962, Record of the Ground Conditions and Numerous Excavation. (This report was included within the MEL Ltd Audit Report 1995).

Miller Environmental Ltd, 1993, Contamination Investigation Report. (This report was included within the MEL Ltd Audit Report 1995).

PB Kennedy and Donkin Ltd, June 1999. Phase II Environmental Risk Assessment, Weir Pumps, Manchester. Prepared for Manly Project Management Ltd.

Arup's, September 2002. North Manchester Business Park – Phase 2 Masterplan. Desk Study for Weir Pumps Site.

The Contaminated Land Exposure Assessment (CLEA). Published by The Department of the Environment Farming and Rural Affairs, March 2002.

Inter-Departmmental Committee for the Redevelopment of Contaminated Land (ICRCL) 59/83 'Guidance on the Assessment and Redevelopment of Contaminated Land' 2nd Edition (1987).

Environment Agency's Environmental Quality Standard (EQS).

UK Water Supply (Water Quality) Regulations 1989.

Construction Industry Research And Information Association (CIRIA). Report 149, Protecting Development From Methane. 1995.

UK Building Research Establishment document Special Digest 1 (BRE SD1) 'Concrete in aggressive ground 2001'.

Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources, Environment Agency R&D Publication 20, 1999 (P20).

FIGURES

APPENDICES

APPENDIX A

GIP FACTUAL GROUND INVESTIGATION REPORT.
(PHASE 1 – AREAS 1, 2 AND 3)

APPENDIX B

SOIL MECHANICS GROUND INVESTIGATION FACTUAL REPORT.
(PHASE 2 – AREAS 2 AND 4)

APPENDIX C

COAL AUTHORITY COAL MINING REPORT

APPENDIX D

AXIS ECOLOGICAL AUDIT REPORT

APPENDIX E

PREVIOUS GROUND INVESTIGATION AND DESK STUDY REPORTS

ENVIRONMENTAL AUDIT, MATHER AND PLATT PARK WORKS, MEL LTD, SEPTEMBER 1995

INCLUDING:- MATHER AND PLATT, RECORD OF THE GROUND CONDITIONS AND NUMEROUS EXCAVATION, FEBRUARY 1962

PHASE II ENVIRONMENTAL RISK ASSESSMENT, WEIR PUMPS. PB KENNEDY AND DONKIN, JUNE 1999.

DESK STUDY FOR WEIR PUMPS SITE, OVE ARUP AND PARTNERS LTD, SEPTEMBER 2002