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1 Introduction

1.1 Instruction

LEE Remediation Ltd has been instructed by JEHU Project Services Ltd (acting on behalf of Dovey Estates Ltd) to assess and determine ground remediation requirements for the portion of the Afan Way development site, Port Talbot which was formerly occupied by a Petrol Filling Station (PFS). These works have been performed under order number P282/A/181/HAE dated 16th June 2008 and follow from a series of site characterisation reports prepared by Ground Investigations Limited and Ecologia. The purpose of the report is to refine the remediation goals for the identified petroleum hydrocarbon impacts associated with the former PFS and put forward an outline methodology for achieving a satisfactory site condition.

1.2 Site Location

The site location is depicted within Figures 1a and 1b, below. The eastern portion of the wider development site, as depicted within the following figures, was formerly occupied by a PFS.



Figure 1a. Location of Site



Figure 1b. The development site and the former PFS

1.3 Previous Reports

This report follows on from site characterisation activities performed by Ground Investigations Limited and Ecologia which identified fuel hydrocarbon contamination impacts to soils and groundwater believed to be associated with former fuel storage and distribution activities at the former petrol filling station.

Previous reports relating to the development site as a whole and the former filling station are understood to include the following:

- Ground Investigation Ltd (GIL). Nov 2004. Afan Way, Port Talbot. Phase Two Geo-Environmental Site Assessment report. Ref.220.01.
- Ground Investigation Ltd (GIL). Dec 2006. Former Service Station, Afan Way, Port Talbot. Validation of Tank Removal. Ref.220a.01.lt.validation.doc
- Ground Investigation Ltd (GIL). Nov 2007a. Afan Way, Port Talbot. Tank Excavation Validation. Ref.220.03.lt4.validation rpt.doc.
- Ground Investigation Ltd (GIL). Nov 2007b. Afan Way, Port Talbot. Geo-Environmental Assessment of Old Tar Tank beneath Unit D. Ref.p220.05.lt3.doc.
- Ground Investigations Limited (GIL). Nov 2007c. Former petrol filling Station, Afan Way, Port Talbot. Assessment of Potential Pollution Risks to Controlled Waters. Ref.p220.03

Following a review of the GIL 2007c report it became evident that further interpretation was required in order to develop a workable remediation strategy for the site. The previous reports had characterised the site thoroughly yet a scheme to remediate the identified contamination had not been developed. This report has been produced to provide clear remediation goals for the site for both soils and groundwater.

The factual information and interpretations presented within the aforementioned reports have also been supplemented by a limited confirmatory investigation performed by LEE Remediation Ltd in June 2008. This confirmatory investigation was performed through the excavation of seven trial pits and one trial trench throughout the former PFS site. Monitoring of the one remaining borehole was also undertaken. The factual findings of the confirmatory investigation are presented in Appendix A and B.

1.4 Proposed Development

The former PFS area of the site is to be redeveloped for commercial retail uses. A single storey building is to be constructed by JEHU Project Services and is referred to on proposed development plans as Unit A.

Figure 2 illustrates the location of the proposed Unit A in relation to the former PFS.



Figure 2. Proposed Development at Afan Way

1.5 Planning Requirements and Report Aims

This report is intended to satisfy the Local Planning Authority that an appropriate remediation scheme for the former PFS portion of the wider development site has been developed. Planning condition 21, associated with the planning approval for the site (Reference P/2004/1778) states,

"Prior to commencement of work on site a detailed scheme to mediate any contamination on the site shall be submitted to and approved in writing by the local planning authority. Prior to occupation of the development a validation report and results prepared by a suitably qualified person shall be submitted and approved in writing by the Local Planning Authority. The scheme shall be implemented in accordance with the approved details."

It is proposed that following on from this report a remediation contract will be let to achieve the prescribed remediation developed herein and furthermore a validation report, verifying that the remediation works have been performed to the approved details and will be used in part to work towards the discharge of planning condition 21.

1.6 Limitations

This report relates solely to the remediation works required within and around Unit A of the proposed development and specifically in relation to fuel hydrocarbons which have been detected within soil and groundwaters as a result of the site's former use as a PFS.

It is assumed that remediation requirements (if any) for remaining areas of the development site have or are being considered by others.

2 The Process of Assessing Risks from Ground Contamination

2.1 UK Contaminated Land Policy

The examination of previous reports relating to the site has highlighted the presence of contaminated soils and groundwater associated with the former fuel storage and distribution activities at the site.

In determining what action, if any, is required to address land contamination issues an assessment of risk is required. Contaminated soils or groundwater may be far from a Greenfield condition but the legislative framework within the UK requires that all land should be suitable for its current or intended use, and must not present or be likely to present unacceptable risks to humans and their property, ecosystems and the water environment (controlled waters).

In determining what constitutes a requirement for remediation under UK legislation the data attained from the previous reports and recent site investigations has been assessed to establish the presence of contamination, and to understand the potential risks associated with its presence. In order to do this it is necessary to understand the relationship between identified contamination and those individuals, property, waterbodies, ecosystems etc (receptors). This relationship, or conceptual site model, is used to establish the presence of pollutant linkages and their significance. Should statutory definitions relating to contaminated land or water resources be met there is likely to be a requirement to perform some form of remediation.

Within the context of UK legislation Part 2A of the Environmental Protection Act 1990 – which was inserted into that Act by section 57 of the Environment Act 1995 – provides a regulatory regime for the identification and remediation of contaminated land Section 78A(2) defines contaminated land for the purposes of Part 2A as:

“any land which appears to the contaminated land in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that –

“(a) SIGNIFICANT HARM is being caused or there is a significant possibility of such harm being caused, or

“(b) POLLUTION OF CONTROLLED WATERS is being, or is likely to be, caused”.

Before the local authority can make the judgement that any land appears to be contaminated land, the authority must satisfy itself that a pollutant linkage exists in relation to the land. A pollutant linkage requires each of the following to be identified:

(a) a CONTAMINANT;

(b) a RECEPTOR; and

(c) a PATHWAY capable of exposing a receptor to the contaminant.

The next step is for the local authority to satisfy itself that the pollutant linkage is a **significant pollutant linkage**. To do this, the local authority must consider the degree of possibility or likelihood of one or more of the following, referring to the definition of contaminated land in the paragraphs above:

(a) SIGNIFICANT HARM,

(b) POLLUTION OF CONTROLLED WATERS, or

(c) HARM (where attributable to radioactivity).

Where any land has been identified as being Contaminated Land, the enforcing authority has a duty to require appropriate remediation.

In the context of redevelopment Planning Policy Statement PPS23 dictates that a Local Authority in granting Planning Permission must be assured that the land in question, following redevelopment, is not capable of being determined as Contaminated Land.



This report is intended to provide a detailed summary of the known contamination within the site and considers the significance of any connection or relationship between the contamination and vulnerable receptors such as waterbodies or future occupiers of the building.

3 Conceptual Site Model

3.1 Introduction

This section of the report summarises the findings of previous investigative works in the context of the Source-Pathway-Receptor model to illustrate the relationship and significance of contamination at the site.

3.2 Sources of Contamination

Previous reports have characterised the site in detail and have recorded the presence of contaminants associated with former fuel storage and distribution facilities.

Principally fuel hydrocarbons have been recorded in soils and groundwater, together with free-phase fuels floating on the groundwater surface. Additional contaminants such as heavy metals and asbestos have not been recorded at concentrations which would be considered unacceptable in the context of the proposed commercial development.

The operational format of the former PFS illustrated within Figure 3 shows the former location of underground storage tanks and pump islands.

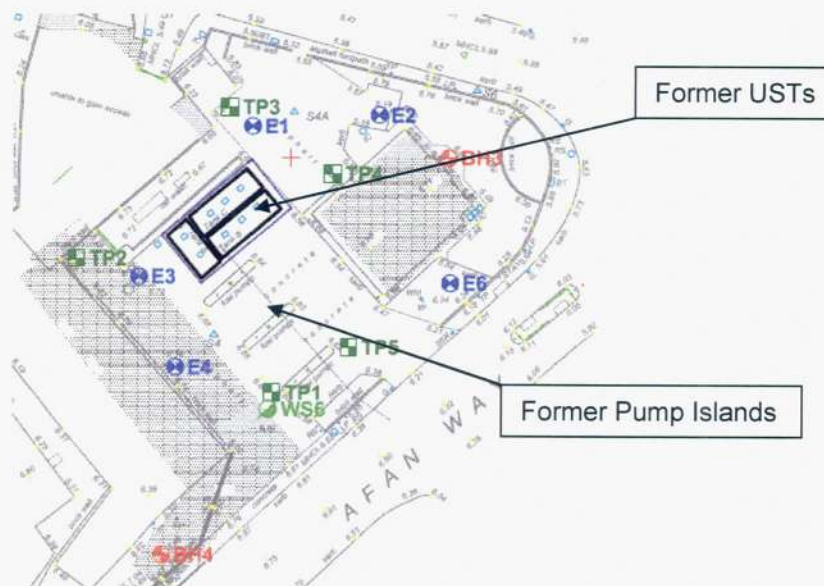


Figure 3. The Former PFS Layout

Due to the recorded presence of free phase hydrocarbons on the groundwater together with soil and groundwater impacts it would appear that a release (or series of releases) of hydrocarbon fuels has occurred at some point from the former infrastructure. Whether the fuel impacts arose from the underground tanks, the fuel pumps or any interconnecting pipework cannot be precisely determined. What is clear from site investigation data is that there are two distinct sources of hydrocarbon impacts within the site boundary, one being the presence of free phase gasoline type impacts on groundwater and the other being related to the presence of diesel type impacts.

Since the removal of the underground tanks and fuel distribution infrastructure in 2006, contaminated soils, groundwater and free phase hydrocarbons within the former forecourt area are considered to represent an ongoing source of contamination to groundwater.

3.1.1 Diesel Type Impacts

Previous investigations have recorded some evidence of a diesel type impact within the north of the site. The Ecologia investigation report recorded free phase diesel type product within Borehole E1 in 2004. Approximately 180mm of free phase product was encountered on top of the water table. However, subsequent investigations performed by GIL have not recorded free phase product in borehole E1 over several various monitoring visits.

A confirmatory trial pitting exercise performed by LEE Remediation in June 2008 (notes provided as APPENDIX A) has confirmed the presence of heavily impacted soils within the locality of Borehole E1 (within LEE Pit LP2) with hydrocarbon concentrations recorded up to a maximum of 10,000mg/kg, the vast majority of which is in the diesel aliphatic range. The impacted soils were encountered above the water table depth at approximately 1.5m to 3.0m depth.

In addition, free phase hydrocarbons were observed above the water table surface within LEE Pit LP2 at a depth of approximately 2.9m (as depicted within Figure 4). The water table was encountered at approximately 3.5m.



Figure 4. Free phase hydrocarbons entering the excavation from the base

Previous monitoring of wells surrounding LEE Pit LP2 have not recorded free phase product and therefore the distribution of free phase in this area of the site is expected to be limited. Despite comprehensive Phase 1 and Phase 2 investigations throughout this area of the site an original source of the diesel impacts remains unknown.

Figure 5 illustrates the distribution of observed and recorded diesel type impacts within the north of the former petroleum filling station site.

Dissolved phase hydrocarbons were recorded within borehole E1 at approximately 18mg/l. Due to the vast majority of the impact being greater than C12 in weight and aliphatic in nature the impact is consistent with a diesel type origin.

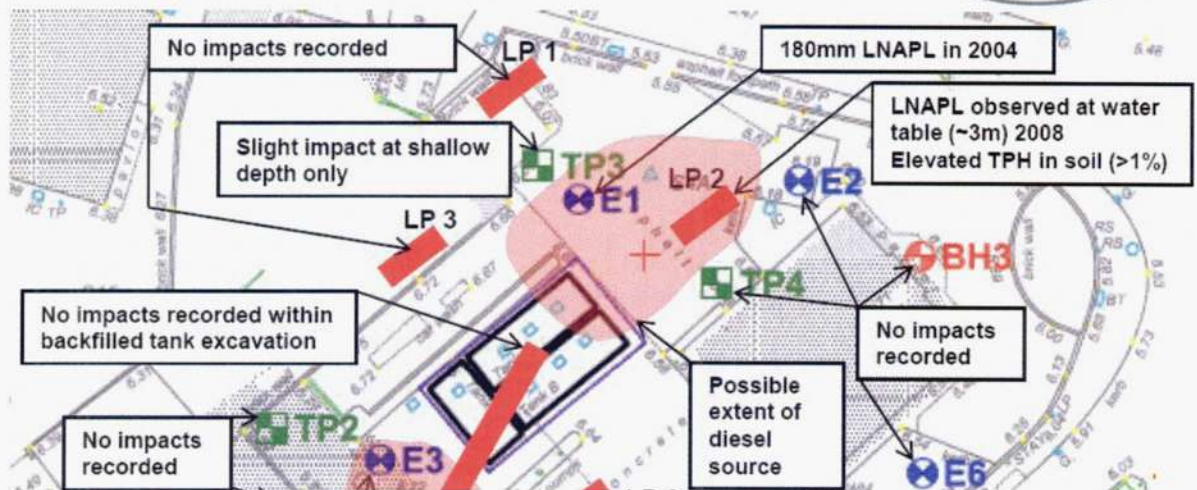


Figure 5. Possible Extent of source of diesel contamination

3.1.2 Gasoline Type Impacts

Various site investigations performed throughout the site by Ecologia and GIL have not recorded extensive or locally high occurrences of gasoline range soil hydrocarbon impacts. However, consistently since 2002, free phase hydrocarbons have been recorded on groundwater within borehole E4. Trial pits excavated in the vicinity of E4 have displayed evidence of hydrocarbon impacts through elevated PID readings, odours and staining. The recent investigation works performed by LEE Remediation recorded a maximum soil concentration of 400mg/kg within impacted alluvial clays within LEE Pit LP7. The analysis is consistent with a gasoline type impact.

Groundwater monitoring of borehole E4 has recorded free phase gasoline type fuel on the groundwater since 2002. Up to 1.3m of free phase fuel has been recorded floating on the groundwater surface since 2002, and recent monitoring by LEE Remediation has confirmed the presence of free phase liquids within the borehole (Figure 6B) and also at the water table surface through trial pitting (LEE Pit LP7) (Figure 6A).



Figure 6A and 6B. Free phase gasoline type impacts in LEE Pit LP7 and recovered from Borehole E4 respectively.

The extent of free phase impacts to groundwater is suspected to be restricted to the vicinity of borehole E4, as monitoring of surrounding boreholes during 2007 has not recorded free phase hydrocarbons (only borehole E4 was present during recent monitoring by LEE Remediation). Figure 7 illustrates the observed extent of gasoline type impacts as recorded during recent confirmatory trial pitting activities.

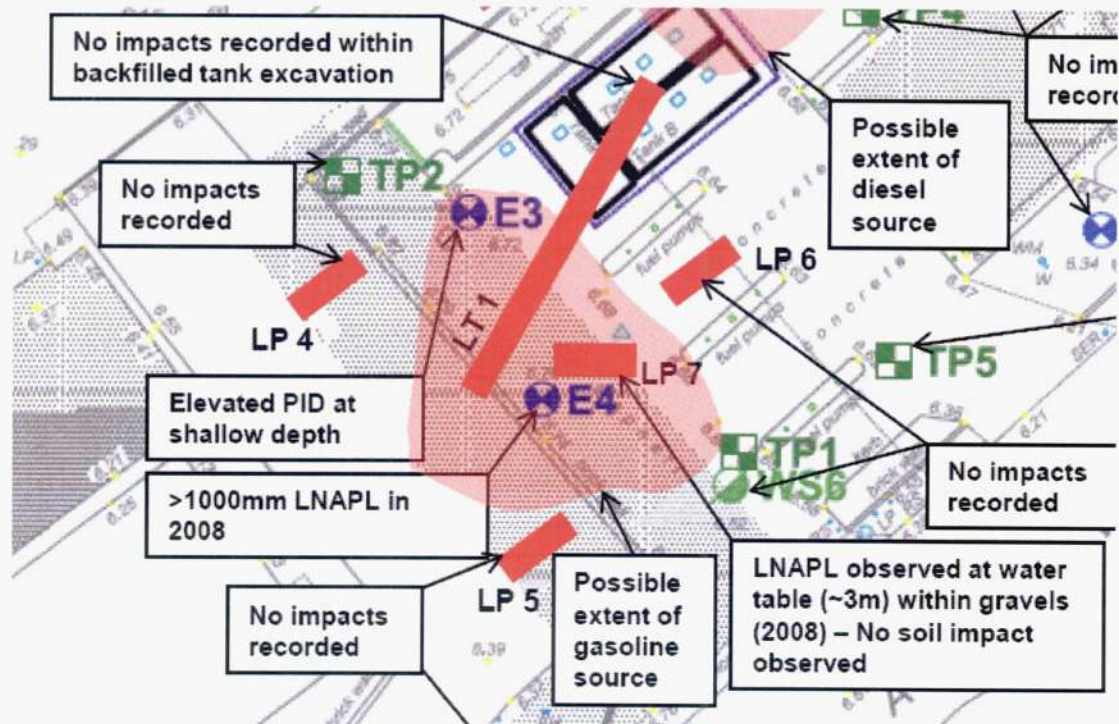


Figure 7. Possible extent of source of gasoline contamination

Dissolved phase impacts have been recorded in boreholes WS101 (east of borehole E4) and WS102 (southwest of borehole E4) suggesting that dissolution of the free phase hydrocarbons is occurring to some extent and contributing to a wider dissolved phase plume. The extent of the dissolved phase impact as measured in October 2007 by GIL was largely limited to the footprint of the proposed Unit A building.

Concentrations of total petroleum hydrocarbons measured in October 2007 were approximately 13mg/l in WS101 and 7mg/l in WS102. The character of the dissolved phase impact is consistent with a gasoline type origin.

Figure 8 illustrates GIL's 2007c interpretation of the dissolved phase impact extents.

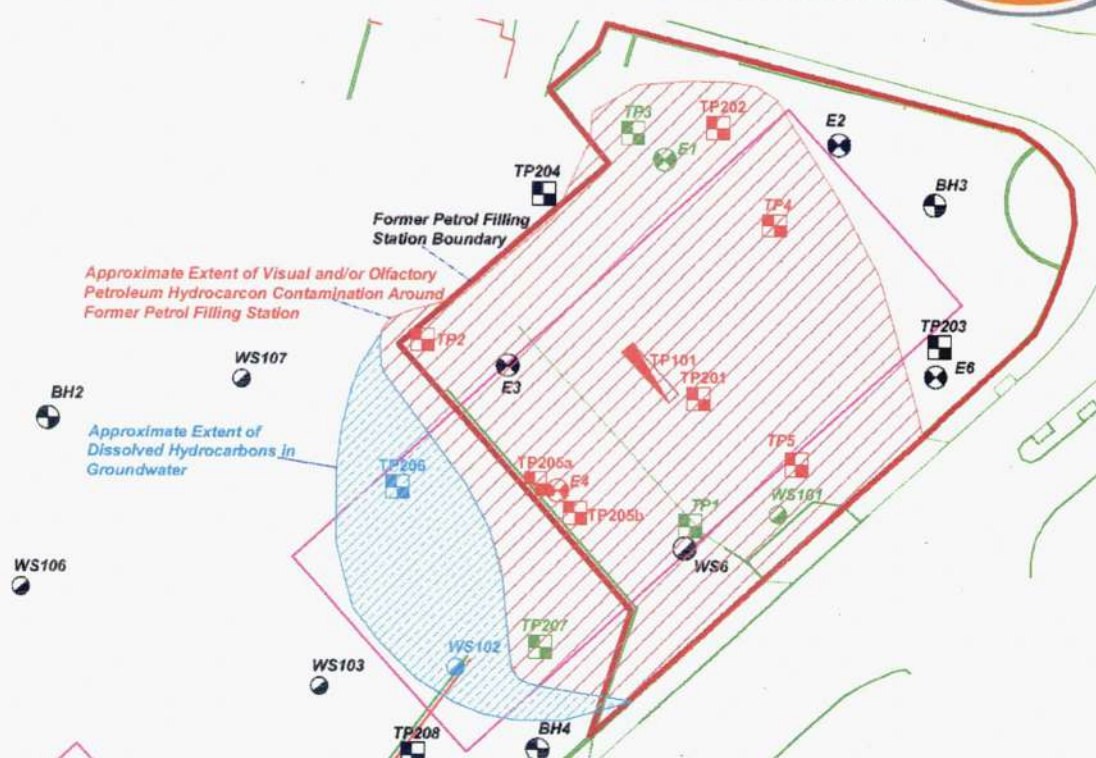


Figure 8. Extent of Dissolved Phase Impacts (taken from GIL 2007c)

3.1.3 Origin of Recorded Impacts

The cause of the release of the hydrocarbons to ground is unknown and due to the absence of fuel distribution and storage facilities a full understanding of how the impacts arose is not likely to become apparent.

The relative absence of shallow soil impacts together with the layered geology of the site would suggest that releases of hydrocarbons have been permitted to migrate to the groundwater table relatively unhindered by overlying soils.

The geology of the site is well documented in previous reports and is summarised as, made ground overlies estuarine alluvium (clays) which in turn overlies fluvioglacial gravels. Should a shallow release of hydrocarbons have occurred to some extent it would be expected to have been upheld by the clays, with further downward migration to the gravels and the water table restricted.

Based on experience of similar sites it is speculated that a release of hydrocarbons occurred in the past and accumulated within the former tank farm area. Due to the size of the tanks the excavation to install the underground tanks would have been approximately 3.8m deep, with backfilling around the tank farm being performed by more granular material. It is this penetration of the estuarine alluvium which is suggested as being the mechanism for a direct release of hydrocarbon fuels to the groundwater, and also to beneath the estuarine alluvium.

The origin of the diesel type impacts is less clear albeit there is evidence of impacted soils at a shallower depth, nevertheless the soil impact has not been widely recorded in the locality and therefore it is possible that deep structures which have penetrated the estuarine alluvium have been or are still present within this area of the site.



The origin of the impacts observed within TP5 is less readily interpretable. Hydrocarbons (of a gasoline nature) were observed within small sand lenses within the estuarine alluvium yet exploratory points between the free-phase gasoline source area and TP5 recorded no impacts.

Figure 9 illustrates the observed vertical distribution of known impacts for the diesel and gasoline free phase source areas.

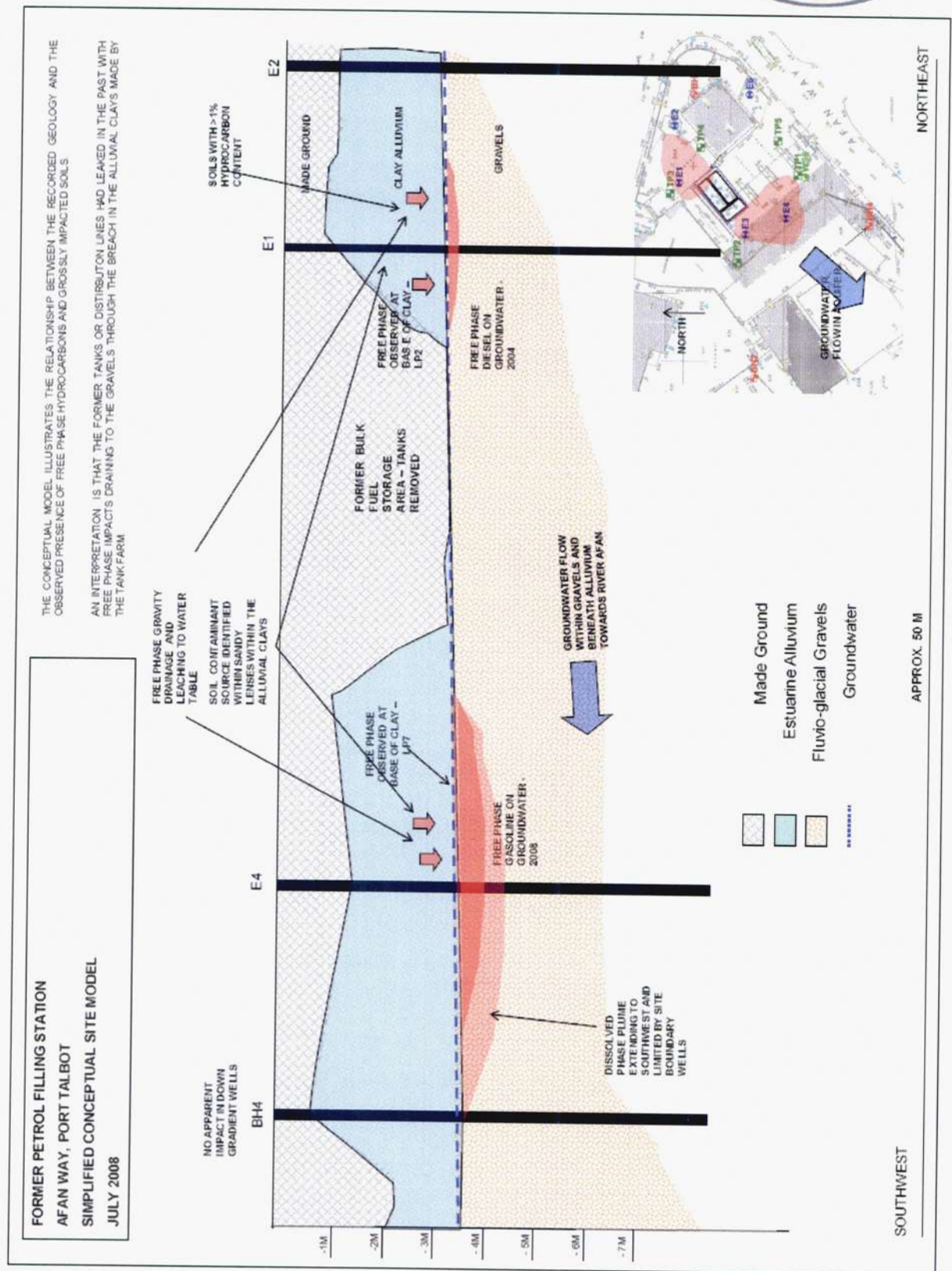


Figure 9. Interpretation of vertical contaminant distribution

3.1.4 Summary of contamination sources

The review of previous reports together with the findings of the recent confirmatory investigations performed by LEE Remediation strongly suggests that there are two distinct sources of contamination present within the former PFS boundary. These sources are,

1. In the vicinity of borehole E4, and characteristic of a release of gasoline fuels possibly directly to groundwater, i.e. from a tank base with little evidence of an associated soil source, and,
2. A release of diesel fuel to soil and groundwater as observed in the vicinity of borehole E1.

A less apparent source, considered to be of lesser significance could be located in the vicinity of TP5. Confirmation of absence/presence would be required during remediation activities.

Figure 10 illustrates the interpreted extent of the observed source areas following further confirmatory investigation works.

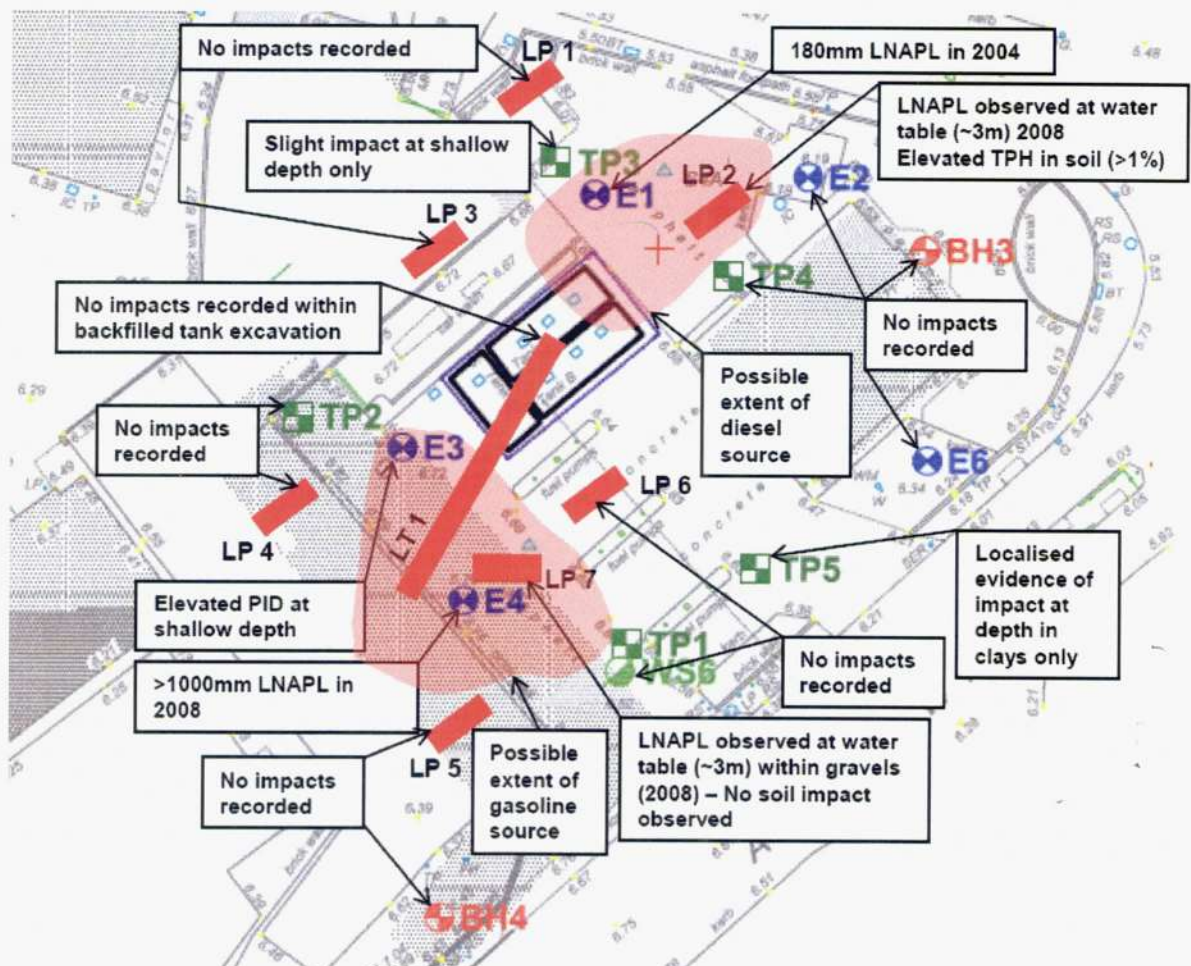


Figure 10. Possible extent of diesel and gasoline contamination source areas

3.2 Receptors and Pathways

Fuel related contamination, consistent with former fuel storage and distribution activities at the site have been identified. In accordance with contaminated land guidance and legislation the significance of such sources should be measured in relation to the interaction of the contamination with vulnerable receptors.

In the context of the future commercial development receptors which may be vulnerable to the known hydrocarbon contaminants are considered to be restricted to human health (future site occupants and users) and controlled waters. Ecological systems (as defined within the DEFRA Circular 01/2006) are not located within the immediate vicinity of the site and therefore are not further considered. Significant harm to site property (specifically buildings) from contamination may occur if vulnerable materials (to hydrocarbons) are used in the construction process. Recommendations to avoid potential risks to building materials are made within Section 5 and are not considered further.

Future site occupants could potentially be exposed to hydrocarbon vapours arising from the impacted groundwater and soils. This vapour migration pathway will need to be considered in respect of proposed remediation criteria for the site. Direct exposure to hydrocarbons in soils is not considered to be a potentially significant pollutant linkage as hardstanding and the importation of a suitable growing media (topsoil) for landscaped areas is proposed. In addition proposed landscaped areas are situated at distance from identified source areas.

The quality of controlled waters such as groundwater, surface waters, including coastal waters are potentially at risk from the expansion of the identified dissolved phase plume into currently unaffected groundwater and ultimately towards the River Afan. Groundwater within the locality is not utilised as a resource (groundwater abstraction for water supply) and due to the proximity of the site to saline waters it is unlikely to be utilised as a resource in the future.

The presence of heavily impacted soils and free phase product on groundwater provides a long term source for continual dissolution of petroleum constituents to groundwater. Affected groundwater is then able to migrate in a south-westerly direction (as calculated by GIL 2007) within the permeable gravel deposits towards the River Afan, 90m from the site's southern boundary.

Data collected from site suggests that the migration of dissolved phase contamination is not occurring at significant rates as dissolved phase impacts appear to be restricted to the footprint of the proposed Unit A. This limited migration is evident despite the presence of a substantial volume of free-phase hydrocarbons at the origin of the plume acting as the source and driver for plume expansion.

Monitoring of groundwater quality, performed by GIL (2007c) has demonstrated a reduction in dissolved oxygen concentrations within the source areas suggesting that some form of biodegradation is occurring, which in turn is limiting the expansion of the plume to some degree.

The geology encountered beneath the site represents the pathway within which contaminated groundwater can migrate towards a vulnerable receptor (such as the River Afan). The geology has been well characterised by the works of Ecologia and GIL and also by the confirmatory investigations performed by LEE Remediation. The degree of linkage between the source areas, the groundwater and more distant receptors is governed by the nature of the geology, the hydrogeological conditions and the physical and chemical properties of the contaminants (fuel hydrocarbons). These physical and chemical properties have been used to calculate the potential migration of contamination from the site in light of new information gleaned from the recent trial pitting exercise (Section 4.0).

3.3 Potentially Significant Pollutant Linkages (post-development)

In summary, the potentially significant pollutant linkages associated with the site in a post-development scenario are presented in Table 1.

Source	Pathway	Receptor
Petroleum Vapours within future buildings originating from impacted soils and groundwater	Inhalation of vapours	Future site occupants and users
Petroleum hydrocarbon impacted soils	Drainage and or Leaching of soils to continually pollute groundwater	Underlying groundwater and surface waters of the River Afan 90m to the south
Petroleum hydrocarbon impacted groundwater	Continual dissolution of free phase product and expansion of dissolved phase contaminant plume.	Currently unaffected groundwaters and the River Afan 90m to the south.

Table 1. Potentially Significant Pollutant Linkages

4 Remediation Requirements

4.1 Risks to Human Health

Future site occupants could potentially be exposed to contamination through vapour ingress into the building. The conceptual model has shown the presence of a source of contamination together and in the context of proposed commercial development a viable exposure pathway could exist.

Provided adequate precautions are adopted during the construction of the building the 'pathway' in the 'source-pathway-receptor' pollutant linkage can be eliminated. This removal of the pollutant linkage is considered the most assured mechanism for the removal of potential vapour exposure risks.

The proposed building will incorporate a concrete floor which to some extent will prove effective at preventing vapour ingress, however joints, and seams will allow some vapour ingress if there is a 'stack effect' within the building.

The damp proof membrane, designed to eliminate vapour (water) ingress into the building fabric will again restrict hydrocarbon vapour entry. However, it would be recommended that the damp proof membrane is upgraded and installed without open joints, i.e. lapped and taped across all seams and edges. In addition, to prevent any accumulation of vapour beneath the building slab it is advised that a passively vented sub-slab granular layer is installed which will allow any build up of residual vapours to escape beyond the building footprint.

Additional exposure to residual contamination could occur should inappropriate materials be used to surround the proposed water supply pipes and also for landscaped areas. For water supply lines the installation of the water supply line which is impermeable to organic contaminants is generally required by the water undertaker on brownfield sites such as former PFSs.

Exposure to soils within landscaped areas is likely to be very limited however, materials used for landscaping should be suitable as a growing medium. Therefore it would be advised to import suitable topsoil for the covering of landscaped area thereby avoiding any doubts over potential exposure to residual contamination, or undesirable construction fill materials.

4.2 Risks to Controlled Waters

The conceptual model has highlighted a potentially significant pollutant linkage in respect of the pollution of controlled waters. In order to assess the significance of the identified contamination sources a modelling exercise, similar to the one carried out by GIL (2007) has been performed.

The modelling exercise has been performed to predict the effect of pollution from identified contamination and to develop remediation criteria which will be suitable for the site's commercial use.

The Environment Agency's Remedial Targets Spreadsheet has been used to calculate the potential pollution arising from contamination at the site. The modelling has been performed in 'forward' mode and is therefore predictive.

The parameters used to construct the model are detailed, with justification, within Appendix D.

The source of contamination has been represented by soil concentrations for both gasoline and diesel type impacts. The maximum recorded diesel type impact at >10,000mg/kg is considered to reflect a soil which is at the lower threshold of fuel hydrocarbon saturation and if left un-remediated could have the capacity to gravity drain free-phase product to the water table. This gravity drainage would be representative of an ongoing input to groundwater which should be avoided, unless detailed long term natural attenuation monitoring can demonstrate that attenuation processes exceed the contamination input to the water environment. Due to the development time constraints it is not feasible to consider this approach and hence an immediate requirement to remediate hydrocarbon saturated soils and free-phase product is accepted.

As 10,000mg/kg (1%) is widely recognised as the lower threshold of saturation for hydrocarbons in soil the predictive modelling has been performed using an initial contaminant concentration of 5000mg/kg based on the diesel character of the sample recovered from Lee Pit LP2.

The results of the predictive soil impact modelling (for the diesel affected area) are presented in Table 2.

Initial Contaminant Concentration (soil) Total TPH 5000mg/kg (diesel character)	Predicted Leachate concentration (mg/l)	Predicted concentration in groundwater (mg/l)	Predicted concentration in groundwater 90m from site's southern boundary (River Afan)
Benzene (<dl)	-	-	-
Toluene (<dl)	-	-	-
Ethylbenzene (<dl)	-	-	-
Xylene (0.25)	0.30	0.009	3.2 x 10 ⁻⁵
C6-8 Aliphatics (6.5)	0.566	0.017	1.04 x 10 ⁻⁴
C8-10 (260)	5.08*	0.013	7.9 x 10 ⁻⁵
C10-12 (600)	1.76*	0.001	6.24 x 10 ⁻⁶
C12-16 (1950)	0.29*	2.3 x 10 ⁻⁵	1.4 x 10 ⁻⁷
> C16 (1680)	0.002*	-	-
C5-7 Aromatics (<dl)	-	-	-
C7-8 (<dl)	-	-	-
C8-10 (2.25)	1.04	0.031	0.00019
C10-12 (41.5)	12.5	0.37	0.0023
C12-16 (275)	41.9*	0.173	0.0011
C16-21 (215)	10.4*	0.019	1.2 x 10 ⁻⁴
>C21 (185)	1.13*	2 x 10 ⁻⁴	1.2 x 10 ⁻⁶
TOTALS		0.63mg/l	0.004 mg/l

* - Predicted leachate exceeds contaminant solubility, following tiers based on max solubility of individual TPH component

Table 2. Predicted contaminant migration at 5000mg/kg diesel affected soil source

Due to the low solubility of the identified diesel fuels limited migration potential is predicted when considering a soil source represented by a maximum concentration of 5000mg/kg. To some extent this is reflected by the continuing presence of free phase diesel within the impacted area and the limited migration of total hydrocarbons within groundwater beneath the site. Predicted breakthrough at the River Afan of the diesel affected groundwater arising from post-remediation conditions is minimal with concentrations of total TPH at 0.004mg/l.

In anticipation of increased impacts being discovered relating to gasoline type impacts predictive modelling of soils affected by gasoline (again at 5000mg/kg) has been performed. The relative proportions of individual TPH components have been developed using the character of gasoline affected soils collected from Lee Pit LP7 (400mg/kg). The individual TPH components have been increased proportionally (divided by 400 and multiplied by 5000) to reflect a 5000mg/kg TPH source.

The results of the predictive soil impact modelling (for the gasoline affected area) are presented in Table 3.

Initial Contaminant Concentration (soil) Total TPH 5000mg/kg (gasoline character)	Predicted Leachate concentration (mg/l)	Predicted concentration in groundwater (mg/l)	Predicted concentration in groundwater 90m from site's southern boundary (River Afan)
Benzene (7.61)	41.8**	0.49	0.0009
Toluene (12.5)	3.05	0.91	9.6 x 10 ⁻¹⁰
Ethylbenzene (90)	113**	0.04	1.5 x 10 ⁻⁵
Xylene (250)	301**	0.235	4.3 x 10 ⁻⁶
C5-6 Aliphatics (11.13)	2.14	0.064	0.0004
C6-8 (50)	4.36	0.131	0.0008
C8-10 (-)	-	-	-
C10-12 (900)	2.63*	0.001	0.00001
C12-16 (1187)	0.177*	2.2 x 10 ⁻⁵	2.3 x 10 ⁻⁷
> C16 (875)	1.1 x 10 ⁻³	7.3 x 10 ⁻⁸	7.4 x 10 ⁻¹⁰
C8-10 Aromatics (913)	421*	1.95	0.0125
C10-12 (437)	131*	0.747	0.0048
C12-16 (325)	49.5*	0.173	0.0018
C16-21 (200)	9.68*	0.019	0.0002
>C21 (77.5)	0.47*	1.98 x 10 ⁻⁴	2.0 x 10 ⁻⁶
TOTALS		4.77mg/l	0.02 mg/l

* - Predicted leachate exceeds contaminant solubility, following tiers based on max component solubility

** - Predicted leachate exceeds contaminant solubility, following tiers based on max component effective solubility

Table 3. Predicted contaminant migration at 5000mg/kg gasoline affected soil source

As with the diesel source area limited migration of the hydrocarbons from the 5000mg/kg soil source is predicted. Breakthrough at the River Afan is predicted at levels less than permissible surface water abstraction standards for hydrocarbons (0.05mg/l DW1). This does not consider any dilution within the River.

To date soils within this area of the site have not been discovered containing hydrocarbons at this level however, such soils are expected close to the water level and along areas where free phase migrated from its current position (such as within the sand lenses).

4.4 Results discussion

The simplified predictive modelling has attempted to reflect site conditions as far as is possible, however various model limitations and assumptions have been made which err on the side of caution and therefore add conservatism to the assessment. As the model is a simple multiplier the conservatism is compounded and this will explain the apparent limited migration as observed at site and the predicted migration to the River Afan.

The solubility of individual TPH bandings and BTEX has been used to restrict the over-prediction of contaminant transport. Solubility limits for individual TPH bands have been taken from Table 8 within the TPHCWG document Volume 3 (available at <http://www.aehs.com/publications/catalog/contents/tph.htm>). This adjustment allows for a reduction in gross misrepresentation albeit the effective solubility of the TPH component in the mixture has not been accounted for, therefore a layer of conservatism is maintained. For BTEX, values for effective solubility have been taken from the US EPA effective solubility calculator, available at <http://www.epa.gov/ATHENS/learn2model/part-two/onsite/es.htm>.

The source area has been defined as the areas shaded within Figure 10. The contaminant source has been represented as a total mass of soil with a uniform concentration of 5000mg/kg. It is strongly suspected that less than 10 % of the soil mass shaded will exceed the 5000mg/kg target as observed through trial pitting where contamination appeared to be restricted to lenses within the estuarine alluvium. Therefore to more accurately reflect the distribution of contaminant

mass within the source, and maintain a precautionary approach the source area has been reduced to 30% of the respective shaded areas.

Infiltration within the model has assumed 5% of annual rainfall will infiltrate through the source areas. Given the proposed development layout infiltration through the building floor will be close to or at zero.

There is limited evidence of biodegradation of dissolved contamination occurring through dissolved oxygen monitoring and through the apparent restricted migration of the dissolved phase plume. For the purposes of modelling literature values have been chosen to represent biodegradation, albeit these have been applied to the dissolved phase only and not to the sorbed contaminant. Adopting a field value for biodegradation would require a detailed field study with no guarantee of a clear value emerging.

The predictive modelling illustrates that following the removal of source soils and free phase product the post remediation condition of the site is unlikely to pollute controlled waters.

Following remediation, the attenuation processes which are currently restricting plume expansion will not have to work against continual inputs from the soil or free-phase sources and will gradually improve the quality of groundwater beneath the site through plume contraction.

4.5 Remediation Targets

The remediation on the basis of protecting the water environment is prescribed on the basis of a removal of contaminant sources and therefore the removal of further ongoing contributions to the groundwater impacts.

In order to remove source contaminants the following targets will need to be achieved;

- Soils within source areas, and within the wider site should not exceed the prescribed remediation criteria of 5000mg/kg. This will ensure that free-phase hydrocarbons on groundwater are not subjected to further additions via gravity drainage of product.
- Free-phase liquids from both distinct areas of the site should be removed to eliminate any further contributions to groundwater impacts.

Active dissolved phase treatment is not considered necessary due to the restricted distribution of current impacts, demonstrating limited migration despite the presence of a substantial product source within the site. The removal of the source soils and free-phase liquids will eliminate any further contributions to the dissolved phase impacts and will allow attenuation processes within the aquifer such as dilution, retardation and biodegradation to reduce residual impacts further over time.

5 Remediation Implementation

5.1 Introduction

Further to recent confirmatory investigations, LEE Remediation recommend that the site is subjected to remedial activity limited to the treatment of hydrocarbon saturated soils and the removal of free phase product from the site. The removal of these concentrated contaminant sources will constitute the removal of the vast majority of stored contamination within the site.

For soils it is recommended that a combination of on-site ex-situ bio remedial treatment and off-site disposal of soils is performed. Excavations should be concentrated in three distinct areas of the site;

- The free-phase gasoline source area – the area surrounding borehole E4 to groundwater depth to remove any further potential for groundwater contamination from overlying soils.
- The free-phase diesel gasoline area – the area surrounding borehole E1 to groundwater depth to remove shallow soil impacts and further potential for groundwater impacts and to confirm the presence or absence of deep structures within this locality of the site.

For groundwater, the removal of free phase product is considered to be most expeditiously achieved through the construction of a series of large diameter remediation wells, providing a high degree of coverage and access to the affected groundwater surface. These wells would allow for the bulk removal of product from the affected gravels through the application of a total fluids recovery process. A period of confirmatory monitoring to demonstrate that the product has been removed to an agreeable asymptotic level, would be required following the product recovery operations. The excavations performed as detailed will permit access to the water table within the source areas, over digging to achieve penetration into the gravels will be required for the large diameter well installation.

Residual contamination, sorbed to soils and within the dissolved phase is not considered to represent an ongoing threat to human health or controlled waters. In the context of the proposed commercial development, and provided that the remediation works are implemented diligently, the site should be considered suitable for its intended use and should not be capable of being determined as contaminated land.

In order to perform and demonstrate to the Local Planning authority that the execution of the required remediation activities has been appropriately performed the following tasks are recommended.

5.2 Remediation Works Mobilisation

The treatment of contaminated soils and groundwater is a licensable activity under the Waste Management Licensing Regulations. Prior to the performance of any soils treatment a mobile treatment license will need to be deployed under the authorisation of the Environment Agency. The deployment of the remediation contractor's mobile treatment license will require certain environmental controls to be put in place to ensure contamination at the site is not exacerbated, spread or inappropriately managed.

Other than standard welfare and personnel decontamination facilities the soils treatment works will require the construction of a dedicated soils treatment bed. This impermeable bed will be used as a platform to store and treat contaminated soils, and will also be used to contain and capture contaminated leachates and run-off waters.

Waters collected from the treatment bed area and those abstracted during the product removal operations would be subjected to above ground treatment using a combination of fluid separation and filtration plant. The plant would need to be housed in a secure location and connected to a mains sewer. An electrical supply to the site would be required to minimise on-site electrical generation costs.

5.3 Soils Treatment

Excavation of soils from the identified source areas, as depicted in Figure 8 would be performed by commencing at the area of greatest impact and radially excavating until clean excavation margins are achieved. Soils at the margins within the excavation would be subjected to laboratory analysis to validate that the soil contaminant source has been successfully removed. The results of the laboratory analysis would be compared to the remediation target criteria to be adopted for the site, (as presented in section 4.4) should the laboratory result exceed the remediation target further soils would need to be removed until the criteria has been met.

Due to the observed presence of contaminant within sandy lenses throughout the site it is expected that a large degree of excavation will be performed compared to recovered contaminated soils. Segregation and processing of soils would need to be performed to ensure a maximum re-use potential re-use and minimum disposal (landfill consumption).

Soils excavated which exceed the prescribed remediation target criteria would be transported to the treatment bed area and segregated into those which are considered suitable for treatment and those which are not and therefore destined for off-site disposal.

Treatment of soils would involve the removal of oversize materials and the addition of nutrients and organic matter to stimulate inherent microbial activity. Soils would be laid out in windrows and conditioned through moisture control and aeration to optimise the bioremediation process.

The concentration of the TPH in soils would be measured at the commencement of treatment activities and through treatment until the remediation target criteria has been achieved (section 4.4). Following validation of successful treatment the soils will be permitted to be re-used for general fill (subject to geotechnical requirements) within the site.

Uncertainties as to the origin of elevated soil vapours and groundwater concentrations remain outside of the denoted principal contaminant source areas (e.g. the area around TP5). In order to demonstrate that the remediation target criteria have been met throughout the entire former PFS site it is recommended that a detailed validation exercise demonstrating the absence of additional contaminant sources is performed. This exercise may prove the absence of such sources or it will initiate additional remediation activities to reduce hydrocarbon concentrations within soil and groundwater.

5.4 Groundwater

5.4.1 Product removal

Both diesel and gasoline type free phase fuel impacts are present beneath the site within two distinct areas. In order to prevent the ongoing deterioration of groundwater quality and the expansion of the existing dissolved phase impacts free phase fuel will need to be removed from the groundwater surface.

The excavation of soils to the water table depth within areas of known groundwater impact will remove the potential for further vertical drainage of product from saturated soils to groundwater thereby removing any further product contribution.

With access to the water table it is recommended that 1.2m diameter ring wells are installed into the affected areas to allow bulk removal of product through total fluids pumping. Once installed treated soils or imported backfill can be used to bring the site surface up to level.

Above ground water treatment plant will be required to separate product from water, contain product and permit consented discharge to sewer of resultant effluents. The discharge consent will need to be negotiated with Welsh Water and is likely to be constrained by permitted concentrations of contaminants and discharge rates.

Following the raising of ground to site levels product removal operations will continue until recoverable product has been exhausted. Monitoring of product levels within the recovery wells will be required to demonstrate technique performance.

5.4.2 Rebound and Dissolved Phase Monitoring

The quantitative assessment of risks has indicated that following source soils and product removal dissolved phase concentrations are unlikely to present unacceptable risks.

However, in order to ensure soils and groundwater have been effectively remediated a period of monitoring post product removal is recommended. This 'rebound' monitoring should be undertaken over an agreed period (typically 1 to 6 months) to demonstrate that ongoing sources of hydrocarbon impact have been removed and that groundwater conditions are allowed to improve due to the absence of further fuel contamination arising from the former filling station.

The rebound monitoring phase will include the measurement of dissolved phase concentrations over the monitoring period to benchmark post remediation groundwater quality.

5.6 Verification of Works

Throughout the remediation works documentation detailing the movement of contaminated soils throughout the site and dispatch from the site will need to be collated (as is required under MTL conditions and Duty of Care).

Results of performance monitoring of treatment activities and excavation margin analysis together with the results of confirmatory sampling works outside of the main source areas would be compiled and issued as a Post Remediation Soils Condition Report for regulatory issue. As the product removal works are likely to extend beyond the soils remediation activities a further verification report demonstrating the successful removal of the product from the groundwater would be issued to include all relevant performance data, post remediation conditions, rebound monitoring and post product removal dissolved phase conditions. In addition, the local Planning Authority should seek verification of the installation of appropriate building materials to prevent any possibility of exposure to residual contamination.

5.7 Construction Considerations

Following the completion of the prescribed remediation additional actions will be required to ensure the elimination of risks associated with the presence of residual low level contaminants.

These considerations will include;

- The use of impermeable (with regard to petroleum hydrocarbons) water supply lines for Unit A;
- The incorporation of basic vapour protection measures to Unit A to avoid any accumulation of vapour concentrations within buildings or pressure build-up. A passively vented granular stone layer beneath the proposed floor slab and a sealed and upgraded damp proof membrane (1200ga) with service entry points sealed is considered appropriate based on similar sites;
- The importation of a topsoil covering (300mm) for landscaping areas to ensure low level contaminants are not available for direct contact with the public.

5.8 Immediate Actions

In order to commence the remediation of the former PFS on Afan Way and promote the improvement of environmental conditions it is recommended that this report is submitted to the local planning authority to demonstrate the intention to implement remediation activities. The issue of this report may prompt dialogue with the Local Environmental Health and the Environment Agency to ensure a full understanding of the remediation intentions.

Upon in principle agreement of the broad objectives presented within this document a detailed remediation strategy will need to be issued presenting methods, material movements and health and safety information. In addition a strategy to verify the completion of successful remediation will need to be provided to ensure compliance with contaminated land management best practice.



APPENDICES



APPENDIX A