Table 9-1- Risk Evaluation Matrix

Probability (P)		Impact (I)					Risk Rating (R = P x I)	Response to Risk
Very Likely	5	Very High	5	Potential to halt project	OR	Potential for major claim or similar	17 to 25	Unacceptable: act now to prevent
Likely	4	High	4	Significant delay on overall project		Major impact on cost	13 to 16	Unacceptable: act now to prevent
Probable	3	Medium	3	Major delay on this task, significant impact on overall project unlikely		Significant impact on cost	9 to 12	Early attention required
Unlikely	2	Low	2	Minor delay on this task, significant impact on overall project unlikely		Minor impact on cost	5 to 8	Regular attention required
Negligible	1	Very Low	1	No significant impact on task or project		Negligible impact on cost	1 to 4	Monitor

Table 9-2- Geotechnical Risk Register

REFERENCE	IDENTIFIED GEOTECHNICAL HAZARD/RISK	CAUSE	RISK BEFORE CONTROL			CONSEQUENCE	CONTROL MEASURES	RESIDUAL RISK			RISK LEVEL
			P	I	R			P	I	R	
1	Variable shallow ground conditions	Significant thickness of made ground of unknown properties over peat deposits that are likely to be of low strength and compressible	4	3	12	Cost (foundation solution) and programme implications	Ground Investigation to profile and assessed shallow ground conditions with an appropriate foundation solution.	1	3	3	Very low
2	Unexpected ground conditions	Variations in ground conditions between exploratory holes	3	4	12	Design variations required; programme and cost implications	Ground investigation coverage to be in line with industry best practice/guidance.	2	4	8	Low
3	Differential settlement	Varying ground conditions / soil strength	2	3	6	Impaired serviceability of proposed building. Cost and programme implications.	Ground Investigation to profile and assessed shallow ground conditions with an appropriate foundation solution to mitigate this risk.	1	3	3	Very low
4	Chemical attack on buried concrete	Aggressive chemical environment within superficial deposits	4	4	16	Increased cost of chemically resistant concrete	TBC when results are provided by laboratory	1	4	4	Very low

REFERENCE	IDENTIFIED GEOTECHNICAL HAZARD/RISK	CAUSE	RISK BEFORE CONTROL			CONSEQUENCE	CONTROL MEASURES	RESIDUAL RISK			RISK LEVEL
			P	I	R			P	I	R	
5	Groundwater	Possible shallow or perched groundwater table	3	3	9	Groundwater present in foundation excavations Softening of sub-grade material reducing bearing capacity values	If shallow groundwater is encountered during the intrusive investigation and therefore control measures during excavation for foundations may be necessary. Drainage controls to be designed accordingly and installed in correct sequence.	3	2	6	Low
6	Services strike	Unidentified buried services beneath the site	2	4	8	Risk of damaging services on site. H&S risk posed to site workers	Ensure up to date services records are obtained and available on site. Location of services to be marked out on site prior to excavations. Relevant Permit to Dig in place and all excavations CAT scanned prior to breaking ground. Existing services to be protected as necessary.	1	4	4	Very low
7	Buried obstructions	Relict foundations/in ground obstructions	1	2	2	Cost and programme implications	Ground Investigation to profile and assessed shallow ground conditions.	1	2	2	Very low

REFERENCE	IDENTIFIED GEOTECHNICAL HAZARD/RISK	CAUSE	RISK BEFORE CONTROL			CONSEQUENCE	CONTROL MEASURES	RESIDUAL RISK			RISK LEVEL
			P	I	R			P	I	R	
8	Japanese Knotweed Deposition Cell	Potential to cause damage to foundations	2	5	10	Structural damages to foundations	Processed Japanese Knotweed buried at depth. It is recommended that advice should be sought from an invasive weed specialist with regards development over this area.	1	5	5	Low
9	Risk associated with historical coal mining	Collapse of workings (recorded and unrecorded) shallow coal seams <30m in southern area of site.	4	5	20	H&S risk posed to site workers and site users Damage to buildings and infrastructure	Further ground investigation updated CMRA and remedial works to stabilise shallow workings	1	5	5	Low
10	Risk associated with historical coal mining	Collapse of workings (recorded and unrecorded) shallow coal seams <30m central, eastern & northern areas of the site.	2	5	10	H&S risk posed to site workers and site users Damage to buildings and infrastructure	No buildings to be constructed in the zone of influence of the treated mine entries, use of geogrids in areas of roadways or parking areas.	1	5	5	Low
11	Risk associated with historical coal mining	Collapse of workings (recorded and unrecorded) shallow coal seams <30m western area of the site.	3	5	15	H&S risk posed to site workers and site users Damage to buildings and infrastructure	Further ground investigation and updated CMRA to identify the requirement for remedial works (if necessary)	1	5	5	Low

REFERENCE	IDENTIFIED GEOTECHNICAL HAZARD/RISK	CAUSE	RISK BEFORE CONTROL			CONSEQUENCE	CONTROL MEASURES	RESIDUAL RISK			RISK LEVEL
			P	I	R			P	I	R	
12	Risk associated with historical coal mining	Collapse associated with shaft and adits (Southern Area) in southern area of the site.	4	5	20	H&S risk posed to site workers and site users Damage to buildings and infrastructure	Further ground investigation updated CMRA and remedial works to cap and stabilise mine entries.	1	5	5	Low

10.0 CONCEPTUAL SITE MODEL AND PRELIMINARY GROUND CONTAMINATION RISK ASSESSMENT

10.1 OVERVIEW

The information presented in the previous sections of this report have been collated and evaluated to establish an initial qualitative risk assessment for the site. A conceptual model of the site has been generated based on information derived from this Phase 1 Geo-environmental Assessment.

The site has been considered with regard to current UK legislation and guidance, namely Part 2A of the Environmental Protection Act 1990 and the Contaminated Land (England) Regulations 2006, as amended, and in accordance with current UK good practice guidelines (for example BS10175:2011).

In general, ground contamination can occur through several causes, particularly from historical operations and activities. Contamination can result from either on-site sources or from on-site migration from off-site sources, leading to long term liabilities under recent legislation for any site owner.

For a risk of pollution or environmental harm to occur as a result of ground contamination, all of the following elements must be present:

- Source, i.e. a substance that is capable of causing pollution or harm;
- Pathway, i.e. a route by which the contaminant can reach a target; and
- Receptor (target), i.e. something which could be adversely affected by the contaminant.

If one of these elements is absent there can be no significant risk. If all are present then the magnitude of the risk is a function of the magnitude and mobility of the source, the sensitivity of the receptor and the nature of the migration pathway.

10.2 DISCUSSION OF POTENTIALLY CONTAMINATIVE LAND USES

10.2.1 Summary of Historical Land Uses

The historical development of the site has led to the ground surface being significantly altered from the natural landscape. Extensive works associated with the former collieries both on site and in the surrounding areas have led to the placement of significant thickness of colliery spoil across the majority of the site.

The associated infrastructure, including the presence of a branch line railway, railway sidings, tramways and tanks as well as the former brickworks indicate the potential for localised contamination to be present in the subsurface associated with the operation of these features and localised spillages. Historical quarries and the potential infilling of these features also indicate the potential for Made Ground of undetermined thickness and composition. Investigation of the former landfill in the western extent of the site (Arup, 2014) indicates the material in this location is limited to soil with limited anthropogenic content. Asbestos sampling of this material was however recommended.

It is also understood that materials were imported to the site for the use in the brick making process. This included hydrocarbon impacted rolling mill sludge and silica waste from the glass making process. Historical reports indicate the presence of up to 1,300 tonnes of these materials which were removed from the site as part of the previous remedial works (2004 / 2005) as summarised in Section 4.0. It is noted that the area of the ground beneath the known storage areas have previously been assessed and no residual contaminants were identified associated these materials.

10.2.2 Potential Contaminants

Due to the varied nature of the historical development on the site, potential contaminants include heavy metals, hydrocarbons (TPH), BTEX, PAH compounds and asbestos. The potential for other contaminants cannot be discounted. The presence of these potential contaminants within the subsurface indicate the potential risk to both human health and the controlled waters of the wider environment (groundwater and surface water).

It is noted that extensive ground investigations have been undertaken across the site primarily in the form of trial pits to allow the collection of shallow soil samples for laboratory analysis, the conclusions presented in the SES Validation report (August 2007) state that there are no risks to human health or the wider environment and no areas of contamination were identified during the ground investigations.

Detailed assessment of the cadmium content of the near surface soils has been undertaken in light of the low pH of the colliery spoil soils which ultimately concluded that the risk to site users within a residential development was limited.

It should be noted that assessments presented by SES included the requirement for the placement of a minimum of 0.5m thick layer of topsoil in areas of soft landscaping to provide a protective cap and a suitable growing medium.

10.2.3 Uncertainty and Limitations

The previous assessments undertaken by SES were completed utilising the relevant screening criteria and risk assessment processes in place at the time of the assessment. A number of the published generic screening criteria have been amended in the time since the assessment and therefore the risk assessment would need to be updated to meet current procedures. Additionally, given the time since the completion of the assessment works, testing would need to be undertaken to confirm the current site status.

Varying suites of testing were undertaken as part of the assessments undertaken by SES. The assessment of TPH were generally limited to bulk values rather utilising speciated testing, with the exception of areas where hydrocarbon contamination was anticipated, including the validation of areas where rolling mill sludge had been stored. As a result of this the site wide risk assessment does not take into account the varying mobility and toxicity of specific hydrocarbon bandings and lacks the resolution to provide a definitive assessment of risk, although widespread hydrocarbon contamination is not anticipated across the site.

Only limited assessment was undertaken to confirm the presence of perched groundwater bodies within the colliery spoil and potential for contaminants to leach into surface waters and groundwater, any future assessment will need to assess the potential for mobile contaminants to be present in the Made Ground strata and colliery spoil deposits across the site. It is noted that a response from NRW through the planning process highlights the sensitivity of the surface watercourses and the requirement for assessment of controlled waters.

The methodology for the assessment of asbestos fibres and asbestos containing materials has improved since the previous investigation and therefore further assessment would be required as part of an up to date ground investigation in due course.

10.3 CURRENT SITE USAGE AND PROPOSED DEVELOPMENT

The site is currently undeveloped with limited access. The following assessment is presented on the assumption that the site will be subject to a future residential development.

10.4 CONCEPTUAL SITE MODEL

The key source, pathways and receptor model is outlined below within the context of potential development of the site.

10.4.1 Potential Sources of Contamination

The main potential sources of contamination on the site are associated with existing features as well as historical land uses on the site as summarised below.

Table 10-1 –- Potential Sources of Contamination

Potential Hazard	Associated Contaminants	Discussion
Colliery Spoil / Made Ground present across the site including infilling of former quarries.	Heavy metals, hydrocarbons, PAH	Significant thicknesses of colliery spoil present across the majority of the site indicating that any potential contaminants are likely to be widespread. The potential presence of asbestos across the site in general has not been discussed in great detail during the previous investigations and will need to be considered in due course. Previous ground gas monitoring did not identify any significant concentrations of ground gases, however given the thickness of colliery spoil recorded on site, the mining legacy this indicates the potential for ongoing generation and migration of ground gases.
	Asbestos containing materials	
	Ground gas	
Localised contamination associated with former industrial activities (brickworks, rail sidings, tanks etc).	Heavy metals, hydrocarbons, PAH	Potential contamination may be present in localised areas across the site. Due to the placement of colliery spoil across the site this also indicates that contamination may be present at depth.
Coal mine workings and mine entries.	Ground Gas generation	As above
Impacted soils associated with former stockpile locations.	Heavy metals, hydrocarbons, PAH	Validation of these areas undertaken by SES did not indicate any residual contaminants associated with the former storage of materials on the site.
Former fuel tanks	Hydrocarbons, heavy metals	Any contaminants are likely to be localised and degraded.

10.4.2 Potential Contaminant Pathways

The following contaminant pathways are considered to potentially be active based on the current site use and proposed development:

Human Exposure Pathways

- Direct dermal contact or ingestion of soils, or inhalation of dust and/or vapours (i.e. human interaction with surface and sub-surface materials).

Environmental Pathways

- Leaching and horizontal or vertical migration through the unsaturated ground, either through permeable sub-surface materials and/or preferential pathways;
- Lateral and vertical migration of groundwater through permeable sub-surface materials and/ or preferential pathways;
- Leaching to surface water run-off/drainage;
- The migration and accumulation of gases or vapours through permeable sub-surface materials and/ or preferential pathways.

10.4.3 Potential Receptors at Risk

The following potential receptors have been identified:

Human Health

- Current site users (limited informal access only);
- Future site users (residential);
- Site workers during the redevelopment of the site;
- Adjacent site users (residential)

Wider Environment

- Secondary A Aquifer;
- Surface waters, including drainage ditches within the immediate vicinity of the site;
- Plant uptake; and
- Building Infrastructure and supply pipes.

10.5 GROUND CONDITIONS RISK ASSESSMENT

The source, pathway, receptor linkages identified in the previous section are outlined and a qualitative risk assessment shown in the following tables.

The risk assessment considers the site within an area context and assesses potential risks to identified receptors in relation to the existing site setting and the proposed development. CIRIA C552 has been used to define the risk rating presented in the Qualitative Risk Assessment matrix, the methodology for which is presented in Appendix D.

Table 10-2 – CIRIA C552 Qualitative Risk Assessment

This matrix is based on CIRIA C552 risk evaluation methodology, definitions for risk ratings is presented in Appendix D						
Source	**Pathway**	**Receptor**	**Consequence of risk being realised**	**Probability of risk being realised**	**Risk Classification**	**Potential risk management requirements**
Made Ground / Colliery spoil deposits across the site.	Inhalation, ingestion and direct dermal contact.	Current site users	Medium	Unlikely	Low Risk	The site has undergone extensive alteration due to the placement of colliery spoil and historical activities. Previous investigations have not identified significant contamination associated with the general made ground / colliery spoil deposits. Due to the age of the previous investigations, a new updated assessment will be required to support any future development. This should include consideration of the risk to human health, controlled waters (groundwater and surface waters) as well as to inform the requirements for suitable growing medium and protection for in ground structures (foundations / water supply pipes). Specific consideration should be given to the potential for asbestos to be entrained within the soils which was not considered in detail as part of the previous assessment. It should be noted that the previous assessment identified the likely requirement for capping to be required across the site in areas of soft landscaping to manage any risks with ground contamination.
		Future site users		Likely	Moderate Risk	
		Construction workers		Likely	Moderate Risk	
	Leaching and lateral / vertical migration	Secondary aquifer	Medium	Likely	Moderate Risk	
		Surface water bodies		Likely	Moderate Risk	
		Plant uptake	Mild	Likely	Moderate to Low Risk	
		Building infrastructure and supply pipes.	Mild	Unlikely	Very Low Risk	

This matrix is based on CIRIA C552 risk evaluation methodology, definitions for risk ratings is presented in Appendix D						
Source	**Pathway**	**Receptor**	**Consequence of risk being realised**	**Probability of risk being realised**	**Risk Classification**	**Potential risk management requirements**
Localised contamination associated with former industrial activities including fuel tanks	Inhalation, ingestion and direct dermal contact.	Current site users	Medium	Unlikely	Low Risk	Areas of localised contamination have not been previously recorded on the site, however the nature of the previous land uses indicate the potential for areas of impacted soils to be present in the sub surface. These are likely to be located within the shallow soils, however areas of impacted soils may exist at depth, based on the raising of ground levels through the placement of colliery spoil. Future ground investigation should be designed to target areas of potential contamination identified during the historical review of the site. The ground investigation results should be used in conjunction with a reactive approach during future development works to identify, and remediate any areas of contamination identified during the development phase. Any associated risk assessment should take into account the potential risk to both human health and the wider environment.
		Future site users		Low likelihood	Moderate to Low Risk	
		Construction workers		Low likelihood	Moderate to Low Risk	
	Leaching and lateral / vertical migration	Secondary aquifer	Medium	Low likelihood	Moderate to Low Risk	
		Surface water bodies		Low likelihood	Moderate to Low Risk	
		Plant uptake	Mild	Low likelihood	Low Risk	
		Building infrastructure and supply pipes.	Mild	Low likelihood	Low Risk	

This matrix is based on CIRIA C552 risk evaluation methodology, definitions for risk ratings is presented in Appendix D						
Source	**Pathway**	**Receptor**	**Consequence of risk being realised**	**Probability of risk being realised**	**Risk Classification**	**Potential risk management requirements**
Ground gas generations from Made Ground, colliery spoil and coal mine workings	Migration and accumulation of gases / vapours	Future site users	Severe	Low likelihood	Moderate Risk	Whilst ground gas monitoring has been undertaken as part of previous ground investigations, due to the significant source potential on the site, further monitoring should be undertaken, including assessment of gas generation rates within deeper areas of colliery spoil and in the vicinity of mine entries to inform risk assessment including risks associated with the use of piled foundations (if needed).
		Construction workers		Low likelihood	Moderate Risk	
Localised contamination associated with stockpiled brick making materials	Inhalation, ingestion and direct dermal contact.	Current site users	Medium	Unlikely	Low Risk	Validation testing of areas of the site used for the storage of brick making materials, including hydrocarbon impacted materials was undertaken following the removal from site. These areas should be considered within any future ground investigation for confirmatory testing.
		Future site users		Low likelihood	Moderate to Low Risk	
		Construction workers		Low likelihood	Moderate to Low Risk	
	Leaching and lateral / vertical migration	Secondary aquifer	Medium	Low likelihood	Moderate to Low Risk	
		Surface water bodies		Low likelihood	Moderate to Low Risk	
		Plant uptake	Mild	Unlikely	Very Low Risk	
		Building infrastructure and supply pipes.	Mild	Unlikely	Very Low Risk	

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 GROUND CONTAMINATION

The site has been subject to extensive alteration due to the historical land uses recorded on the site, including the Emlyn Colliery and subsequent brick works. Within the context of ground contamination, this has the potential to impact the site in terms of:

- contamination associated with the general made ground and colliery spoil which is present across the majority of the site in significant thicknesses
- localised contamination associated with spills and specific on site activities.

The former storage of materials on the site for brick making also has the potential to have impacted the sub-surface, although validation testing at the time of the removal of these materials from site indicated that this is likely to be limited.

Due to the time elapsed since the previous assessments, further ground investigations will be required to confirm ground conditions across the site and to facilitate an up to date ground contamination risk assessment in line with current guidelines and best practice. This should include an assessment of the potential for asbestos containing materials and fibres to be entrained within the made ground, which was not considered in detail as part of the previous assessments.

The ground investigation should be designed to provide a comprehensive assessment for potential contamination to impact human heath as well as groundwater and surface water bodies. The assessment should allow an up to date conceptual model to be developed outlining the active Source – Pathway – Receptor linkages in operation on the site, taking into account the relative sensitivity of the proposed end users and the controlled waters on the site.

Based on the available information reviewed within this document, the potential requirement for the placement of a clean capping system in areas of soft landscaping has been identified. Further assessment will be required to determine whether on site materials (including topsoil) will be suitable for use within the capping system in lieu of imported materials to act as a suitable growing medium. In residential plots, this capping system would generally be required to be a minimum of 600mm in thickness, although the thickness may be reduced in areas of public open space through the use of a geomembrane. It should however be noted that the use of geomembranes are not usually considered appropriate in residential plots.

In the event that areas of localised contamination are identified during the ground investigation or subsequent development works, the ground contamination risk assessment will need to be revised and removal of impacted soils may be required to manage any risks to the identified receptors.

A review of historical planning applications for the site has indicated that planning conditions were applied to the relevant planning consent with respect to ground contamination. It is however noted that that these conditions are considered to be standard requirements for brownfield sites and provide an industry standard framework for the assessment, management and remediation of contamination. It is anticipated that a similar requirement would be applied to any future planning application.

11.2 GEOTECHNICAL

Measured properties of samples taken from the earthworks (2006) during the course of the work met or exceeded the requirements of the specification, and subsequent ground investigations undertaken at various parts of the site have also confirmed this, such that the compacted fill has sufficiently high strength and low compressibility to support the structures and pavements proposed for the development at the site, as set out in the designs.

Given the anticipated ground conditions it is considered likely that traditional shallow foundations (Likely to be rafts and/or strip and pads) will be suitable within the context of the proposed development. Suitable founding strata are likely to be identified within Made Ground deposits.

Soft strata such as peat and mine waste tailings are present below the fill placed and the presence of these materials below the development will be considered in the foundation design for each structure proposed. The lateral extent and elevation of these strata have been determined by probe hole drilling on a grid pattern in September 2006.

Near surface soft areas have been excavated and removed off site and unsuitable materials found in cutting were excluded from the fill.

Where required, geogrid reinforcement and drainage material were incorporated into the fill to ensure long-term stability.

Areas susceptible to mining have been designated zones requiring further investigation and treatment.

11.3 COAL MINING RISK ASSESSMENT

An updated Coal Mining Risk Assessment has been presented for the site based on the data provided by the Coal Authority and results of remedial works previously undertaken on the site. The results of the assessment shows that for the majority of the site (central, eastern and northern areas), there is a low risk of ground instability as a result of recorded/unrecorded shallow (<30m) mining and mining geology.

The mine entries located in this area (Shaft 258-213-033 and Adit 258-213-123) were treated as part of the previous remedial works. No buildings should be constructed over these treated entries, but roadways or parking areas are normally permitted with use of geogrids. No further remedial works for mine workings are deemed necessary in this area.

In the southern area of the site, there is a high risk of ground instability. This is a consequence of recorded/unrecorded shallow (<30m) mining and mining geology being present in addition to the five former mine entries (four shafts and one adit) being present. Further investigation and remedial works are required to support a future development on the site

Although there is limited borehole data for the western part of the site, it is likely that any workings will be at sufficient depth so as not to be deemed high risk. However, this will need to be confirmed by further investigation (rotary probe drilling).

11.4 RECOMMENDATIONS

Where there is a low risk of ground instability as a result of recorded/unrecorded shallow (<30m) mining and mining geology as shown on Figure 3, supplement ground investigation and assessment should be undertaken to support the detailed design of the development. It is envisaged that the scope of such work should include the following:

- Confirm ground conditions, material geotechnical parameters and soil contaminants to inform an updated ground contamination GQRA for human health and the wider environment and geotechnical assessment to confirm foundation and pavement design.
- Ground gas risk assessment in line with the requirements of CIRIA 665, including the consideration of gas generation on site as well as mine gases derived from shallow workings and mine entries.
- Soil infiltration testing to inform drainage design and support an application to the SAB with regards to the use of sustainable drainage on the site.

Based on the previous investigations and assessment reviewed as part of this report but critically subject to the findings of the supplementary ground investigation and proposed design for the site the following activities may also be required.

- Development of a remedial strategy and verification plan to manage any risks associated with previously un-discovered ground contamination on the site encountered during construction and the installation of clean capping in areas of soft landscaping. Localised removal of previously undiscovered contaminated soils may also be required.
- Implementation of a Materials Management Plan to document the re-use of soils on the site and the importation and disposal of soils to facilitate the development. This document should be completed in line with the requirement of the CL:AIRE document 'Definition of Waste: Code of Practice.
- Asbestos management plan to manage materials which are impacted by asbestos containing materials and asbestos fibres. This should include requirements to control the exposure to asbestos during the development phase.

Where there remains a high risk of ground instability as a consequence of recorded/unrecorded shallow (<30m) mining, mining geology and former mine entries being present further investigation and remedial measures should be carried out first. Additional investigation works are likely to include geophysical surveys and trenching to locate mine entries and rotary probing to confirm presence of shallow workings and the backfill condition of mine entries. Upon completion, remedial works comprising excavation, re-compaction, grouting (shallow and deep) and backfilling and capping mine entries are likely to be required. The southern area of the site has been previously zoned based on likely additional investigation and remedial works required. Any development in this area will also be subject to the requirements detailed above for the low risk areas.

Advice should be sought from an invasive weed specialist with regards to development over the Japanese Knotweed Deposition Area. Given the treatment process adopted, depth of burial and time that has lapsed since completion, should any re-growth have occurred it would be visible/present at surface. If no re-growth is present and the deposition area remains undisturbed, construction above the area is likely to be permitted.

12.0 REFERENCES

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